THE BREEDING & FEEDING OF FARM STOCK

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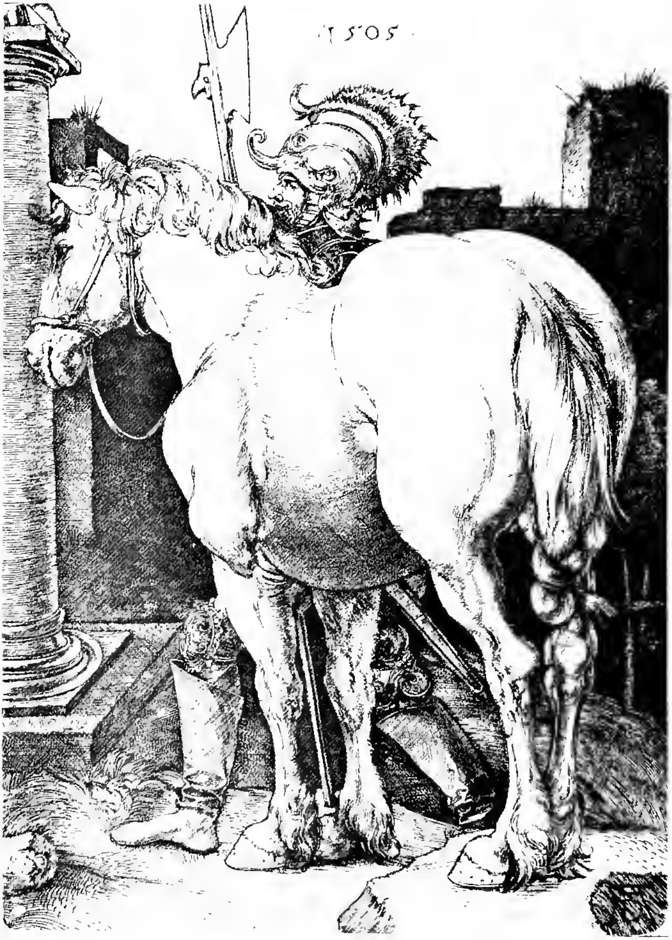
THE BREEDING AND FEEDING OF FARM STOCK

UNIFORM WITH THIS VOLUME

POULTRY KEEPING
PRACTICAL DAIRYING
CROPS AND TILLAGE



THE GREAT HORSE
From the Engraving by Albrecht Dürer

THE BREEDING AND FEEDING OF FARM STOCK

BY

JAMES WILSON

WITH TWENTY-ONE ILLUSTRATIONS AND DIAGRAMS

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black in colour; but the Belgic tribes may have had some of the same race which had a brown stripe along the back and a like-coloured band round the muzzle. Though the British met Cæsar with horsemen and chariots,[1] the horses of the Belgic tribes only were large enough to be ridden. The nearest modern descendants of the Celtic cattle and horses are the cattle now in Wales and Kerry and the ponies in Shetland and the mountains of Britain. It scarcely needs saying that the progress of civilization in Britain would not have been as it has been, had not larger and stronger cattle and horses been brought into the country. During the dozen centuries following the Belgic invasion, Britain was invaded by four other peoples—the Romans, the Anglo-Saxons, the Norsemen, and the Normans—each of which brought in new kinds of stock which, however, were not always larger and stronger than those in the country before them but merely such as happened to be living in the country their owners had just left.

Though Cæsar came to Britain chiefly to prevent the natives sending help to their kinsmen in Gaul and hindering Rome in that country,[2] the purpose of later expeditions was to extend the Roman Empire in Britain, where the natives were not to be driven off but, under Roman soldiers and civilians, become a source of revenue for the state and profit for merchants and traders. To this end, towns and camps and subsidiary military stations were built and roads laid down not only to connect them together but with Rome itself. For the transport of stores and the materials which the scheme of occupation involved, the Celtic cattle were too small and feeble, and the Romans imported a heavier kind raised by their own farmers. These cattle were generally white, with black markings about the muzzle, eyes, ears, and lower limbs. They had upturned horns, sometimes long and wavy, which, if they served no other purpose, helped McKenny Hughes to prove their introduction to Britain.[3] It has been inferred, since they developed the woollen industry,

[1] Cæsar, Book iv, chapter xxiv.

[2] Cæsar, Book iv, chapter xx.

[3] In a paper communicated to the Society of Antiquaries in 1896 "on the More Important Breeds of Cattle which have been recognized in the British Isles in Successive Periods."

of which Winchester was a centre, that the Romans also introduced a better woolled variety of sheep, but, if any improvement was effected, it must have been in quality only, for, till three or four centuries ago, the average weight of an English fleece was little over a pound.

As the Roman occupation of Britain lasted nearly four centuries and the northern frontier was once maintained for about forty years to the level of the Forth and Clyde, the stock the Romans brought in had time enough to be distributed not only through England but also in Scotland.

The downfall of Rome let in the Anglo-Saxons and their stock from the country round the Bight of Heligoland. To some of them, the new country was already known, for they had ravaged its eastern and southern coasts; and a small band of Jutes, under Hengist and Horsa, had helped the southern Celts to drive the invading Gaels (some of whom had come over from Ireland) and Picts back into the North, on condition that they received a grant of land in return. But the contract was scarcely fulfilled when they who had received the land decided to have more, and, with reinforcements from their friends at home, turned upon the Britons and drove them into the West. This, which was done in Kent, was an example of what might be done elsewhere by other bands; and, in little more than a century, the people of the eastern half of Britain, from the Forth to the English Channel, were exterminated or expelled and their land occupied by Saxons, Jutes and Angles. The method of the invaders was to send over bands of warriors and, when these had driven off the natives, bring over their own women and children and such of their stock and other belongings as could be carried. Thus, their conquest was only gradual and piecemeal, and, though they were generally strong enough to keep off the surviving natives, they were not numerous enough to populate and settle the whole of the conquered land at once. Here and there, on suitable sites, villages were established round which the necessary land was cultivated, but the intervening wastes and forests were left to nature till such time as the population required them. These places were inhabited by the wild game of the country and also by descendants of the domestic stock of Roman times which, in the confusion, had escaped and become feral.

Of the Anglo-Saxon domestic stock we can be definite only as to the colour of their cattle, which were red. They were probably larger than the Celtic cattle, for they had long been used for draught. Till two or three centuries ago, their descendants predominated from Yorkshire to the Channel.

Excepting that they arrived several centuries later, the Norsemen came to Britain as the Anglo-Saxons had come: as plunderers first and settlers afterwards: only, because of the positions of the countries from which they had come and the seaworthiness of their boats, their journeys were not confined to the east, but extended round the coasts of Britain and Ireland. Naturally, their strongest settlements were on the northern and eastern coasts of Britain, for, though they set up kingdoms and founded cities in Ireland, and left earldoms in the Hebrides and Man, their settlers in the west were never numerous enough to keep their language alive or even to leave such strong traces of it as are to be found in the north of Scotland. Of the Norsemen's cattle we can speak without hesitation, for they differed decidedly from those in the country before them. They were small, short-legged, narrow-backed, big-bellied creatures with scythe-shaped hind legs, usually light dun in colour, and hornless. They do not seem to have penetrated inland excepting in Ireland, for, in England and Scotland, their early traces are all found near the coasts: in the Orkneys, the Hebrides, Galloway, Devon, East Anglia, Yorkshire, and the north-east and north of Scotland. In other districts they have died out, but in Galloway, East Anglia and the north-east of Scotland, have united with other cattle to produce the modern Galloways, Red Polls and Aberdeen-Angus.

Though the Belgic tribes in Britain and the Romans both had horses fit to be ridden, the Anglo-Saxons did not become horsemen for several centuries.[1] Indeed it was not till their

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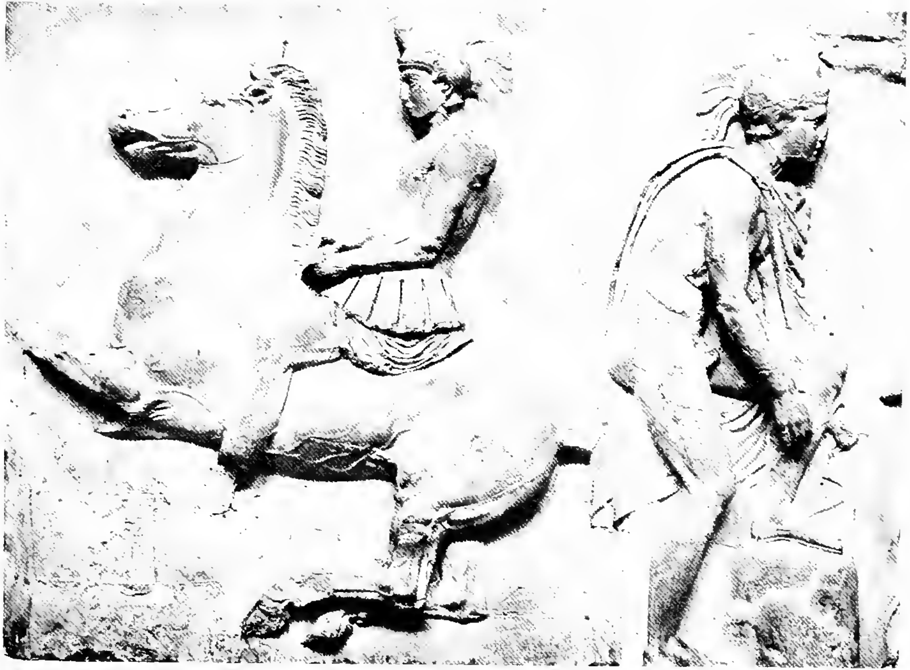
[1] In the sixth century, Procopius wrote: "These islanders . . . fight on foot" . . . and "know not how to ride." Ridgeway's "Origin and Influence of the Thoroughbred Horse," p. 353.



ROMAN HORSE

From the Parthenon Frieze

military leaders—their *principes*—who, with their wise men—their *magistratus*—were at one time popularly elected, became virtual masters of the people and the land and set up what we now call feudalism.

Formerly every man was liable for military service, but now the chief or lord, with his own men-at-arms, leads out his henchmen or thanes, with theirs; and the rest of the men are compelled to stay in their villages at home and till the land. In return for his services, the thane receives from his lord a grant of land which is his feodh or fee, whence come the words feu, feudal, feudalism. In former times, the tribesmen marched and fought upon foot, now the lord relies upon a smaller number of cavalry.

Though Bede tells us that Oswin gave " an extraordinarily fine horse to Bishop Aidan,"[1] it is not till the year 787, at the first recorded coming of the Norsemen, that a horse is mentioned in " The Anglo-Saxon Chronicle " : " In this year Breohtric took King Offa's daughter. And in his days came the first three ships of Northmen from Haerethaland. And the reeve rode to them to drive them to the king's tun, for he knew not what they were. And they slew him there." Shortly afterwards, in Alfred's wars with the Danes, cavalry were used upon both sides, but, as to the horses of the Anglo-Saxon cavalry, we can only speculate. Most likely they were descended from those ridden by the Belgic Britons and the Romans, but it is possible that, through intercourse with the continent after the introduction of Christianity, horses of a heavier type may have been imported.

The Lower Rhine is the source to which all modern heavy horses can be traced, and, from his contemptuous description, some of those which Cæsar saw seem to have been of this heavy kind : " While the Gauls take great delight in their horses and pay large sums for them, the Germans do not use imported horses but, by daily exercise, train the native born ones, which are plain and ill-shapen, for the severest work. In cavalry actions, they frequently leap from their horses and fight upon foot. They train them to stand still and run back to them when there is need. Among the Germans, nothing is considered more disgraceful or spiritless than a saddle."[1] In this description, we see a horse which is not tall, for, then, he could not be readily mounted without a saddle, nor small, for, then, he would neither be ridden nor be plain and ill-shapen, and not nimble enough to be lightly turned and handled in action at close quarters. Yet this horse must have been stout and enduring, for Cæsar tells us that the Tenchteri and the Usipii, two tribes living on the right bank of the Rhine, surprised the Menapii through their cavalry covering a three days' march in a single night.[2] Nor did these German cavalry deteriorate, for, in Tacitus, we find that "the Tenchteri excel in the use of trained cavalry, and the Chatti are no more to be praised for their foot than the Tenchteri for their horse."[3]

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[1] Ecclesiastical History, Book iii., chapter xiv.

While it left the Britons exposed to the Anglo-Saxons from the north-west of Germany, the Roman downfall left the inhabitants of Gaul similarly exposed to the Germans near the Rhine. The two conquests differed, however, in some details. The Franks, as they who conquered Gaul came to be called, were already horsemen. When they had found a footing on the western bank of the Rhine, they sent out wide marauding parties which returned with booty and plunder. In time, however, as they went farther and farther from their base, the marauders ceased to return, but established themselves among the overawed and defenceless Gauls; and, as in England, they who were masters of the land and the people found their horses useful in maintaining their authority and power.

Early in the eighth century, the Franks were invaded by the Saracens who had come originally from North Africa, from which they had brought horses of the kind which was brought to England long afterwards to produce the Thoroughbred. The Saracens overran France as far as the Loire, but in 732, at Poictiers, near Tours, were severely defeated by the Franks under Charles Martel and fled speedily back to Spain. Thus, till this battle, horses imported to England from France may have been of Gaulish, Roman, or Rhenish ancestry, but, afterwards, of African or Spanish also.

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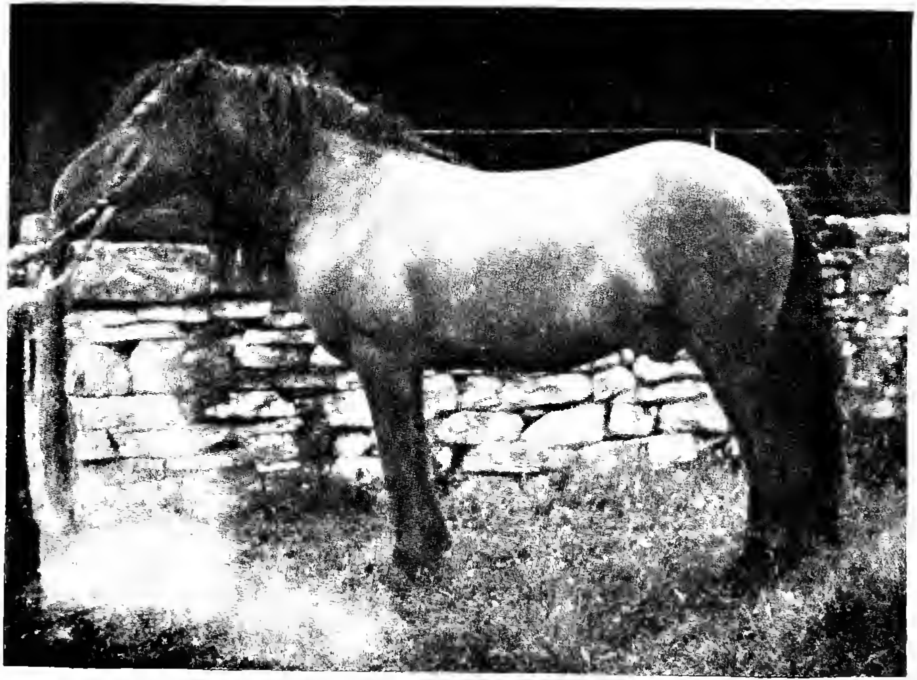
[1] Gallic War, Book iv. chapter ii.

[2] Gallic War, Book iv. chapter iv.

[3] Germania, chapter xxxii.



TYPICAL NORSE HORSE

From Sir H. de Trafford's "Horses of the British Empire."

Keary, the author of "The Vikings in Western Europe," was of opinion that the Norse horses were merely pack horses which may have been superior to the cavalry they met in England but inferior to those they met in France. "The Danes themselves had long made good use of horses, but chiefly for the sake of transport. On horses—a mounted infantry, or even as I have said a sort of horse marines—when away from their ships they scoured the country,"[1] and "The one advantage which the Franks at present possessed was in the superiority of their cavalry over that of the invaders, who perhaps hardly as yet possessed that arm." [2]

The data from which an idea of the Norsemen's horses might be drawn are few and indefinite, but, if we remember that the Norsemen were not always rievers and plunderers but became the great carriers of Western Europe, set up trading centres in many places, and distributed merchandise by land and sea, we shall look for the descendants of their horses where they settled and traded, namely in Iceland, Ireland, the western coasts of Britain, and the north of Scotland. In these places, we find a colour, dun, which is still common, though exceptional elsewhere. The horses of this colour are of different types, but the majority are garrons of thirteen or fourteen hands, with stout limbs, thick bodies, straight shoulders, plain heads, and in many cases, moose noses. Horses like these are very common in countries from which the Norsemen came, and travellers may see them in the hackney carriages of such places as Stockholm, Gothenburg and Copenhagen.

It is from the horses brought in by the Normans that the larger and medium sized British horses are chiefly descended. The Normans were the descendants of a stream of Norsemen which conquered and settled in France while the other stream was conquering and settling in Britain. They drove the Franks from the country lying along the southern shores of the English Channel, seized the land and continued to rule the people on the feudal system. It is not to be supposed that they held any superfine theories about stockbreeding, but that they seized the horses they liked best and bred from them with no other idea than that their stock would be like them. At any rate, the horses they brought with them to England were stronger and swifter than those there before them. Judged by their looks on the Bayeux Tapestry, which is a pictorial representation of the Conqueror's expedition worked either by his brother or his wife, the Norman horses were stout, clean-legged, good-looking animals, about fourteen hands high, of the kind which usually carries John Bull when he goes riding.

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[1] p. 302.
[2] p. 277.

For the next six centuries, the horse was the special care of the kings of England, whose object was to have one which, above all things, was suited for war. Till about 1190, the soldier was protected below the head only by the hauberk—the heals beorg or neck shield—made of interwoven links which added but little to his weight. Then the hauberk was lengthened till it became a sack or mail protecting the body to the knees: only to be superseded by plate about 1300. To carry these increasing weights, stronger and still stronger horses became necessary. Even in the Conqueror's own reign, "Roger de Bellesne, Earl of Shrewsbury . . . obtained leave of the king to import from Spain a number of stallions of great value. These stallions, indeed, were said at the time to be 'the best procurable in Spain.'"[1] "The Exchequer Rolls for 1160 show that an allowance of one mark was made to William de Sancto Mauro, 'for maintenance at Winchester of the King's (Henry II) horses, which the Treasurer had brought from beyond sea.'"[2] Both these notices may refer to horses of the speedier kind which the Saracens had brought to Spain; but, in King John's reign, that is between 1199 and 1216, just after the introduction of chain mail, "no less than one hundred stallions of large stature were imported from the Low Countries,"[3] and Edward the Third, who had cavalry studs at many of his manors, sent Sir John de Brocaz and his son to buy horses in Gascony for the Crecy campaign and was, at one time, "indebted to

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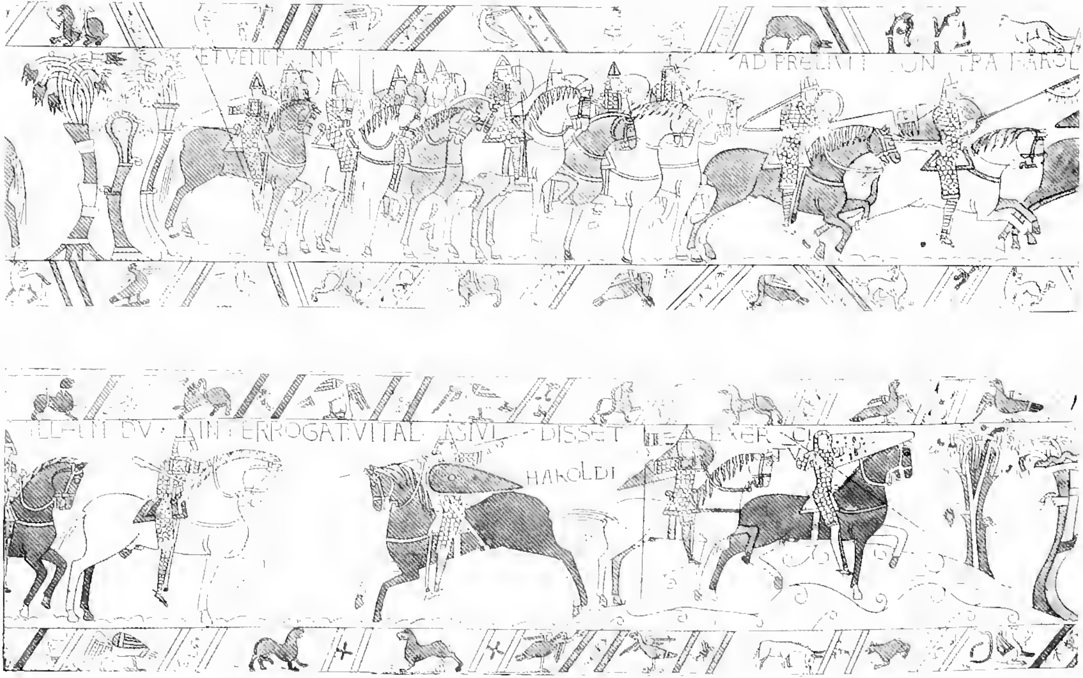
[1] Quoted from Tozer's "The Horse in History," p. 107.

[2] Ridgeway's "Origin and Influence of the Thoroughbred Horse," p. 355.

[3] *Ibid.*, p. 356.


ET VENERUNT
AD PRELIUM CONTRA HAROL
WILLELM DUX INTERROGAT VITAL SI VIDISSET EXERCITU
HAROLDI

NORMAN HORSES
From the Bayeux Tapestry

the Count of Hainault to the extent of 25,000 florins for horses."[1]

Though no more similar importations are recorded, later governments still favoured the increase of the heavy horse, but employed other methods. Henry VII forbade the export of horses and mares of the value of six shillings and eight pence or more,[2] but Henry VIII was still more drastic, for, in 1535, he passed an act forbidding the use, in certain places, of stallions under fourteen hands and another in 1541 which raised the height of the stallion to fifteen hands. These acts have such an important bearing upon the later history of horse breeding in England that it will be well to know more about them. Till after the Black Death, in the middle of the fourteenth century, England was farmed on the village system. Towers and castles had been built by Saxon and Norman lords and monasteries and abbeys by the church, but these stood usually near one or other of the villages subject to the lord or the churchman. Each village lay in the midst of its three tillage fields, against which abutted, where convenience and the nature of the land had placed them, a grazing for cows, another for bullocks, and a meadow for hay. Farther away lay the common grazing for young stock of all kinds, and the forest, where swine were raised and whence timber and firewood were drawn. Rough fences were raised round the corn and hay in spring but taken down again after harvest, to have the stubbles grazed. The whole was unenclosed and open, as were the vast stretches of unreclaimed forest, moor, heath, and waste which lay between the village and its neighbours upon every side.

After the Black Death, which brought the population down from about four millions to two and reduced their revenues in proportion, the landlords and churchmen sought to recover themselves by grazing the unoccupied lands for wool, which was then wanted in Flanders and Italy and beginning to be in good demand at home. But, to economise in herding and prevent encroachments on undisputed as well as disputed land, the grazings were closed in by fences. Thus, till the village system died out, in the seventeenth and eighteenth centuries, the village lands remained unenclosed, while those in the hands of landowners severally and farmers to whom they had been rented were enclosed.

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[1] Sir Walter Gilbey's "The Great Horse," 2nd ed., p. 19.

[2] *Ibid.*, p. 21.

The 1535 act of Henry VIII applied to enclosed lands only, but that of 1541, by including the commons, to all lands in the greater part of the country where horses were bred and grazed. The pertinent part of the first act reads as follows: "It is provided that all Owners or Fermers of parks and enclosed grounds of the extent of one mile in compass, shall keep two Mares, being not spayed, apt and able to bear foals of the altitude or height of thirteen handfuls at least, upon pain of 40/-."

"A payment of 40/- is imposed on the Lords, Owners, and Fermers of all parks and grounds enclosed as is above rehearsed, who shall willingly suffer any of the said Mares to be covered or kept with any Stoned Horse under the stature of fourteen handfuls."[1]

The 1541 act reads: "No person shall put in any forest, chase, moor, heath, common or waste (where mares and fillies are used to be kept), any Stoned Horse above the age of two years, not being 15 hands high, within the SHIRES and territories. . . ." Here follow the names of twenty-six shires and territories, but we shall see better where the act applied if we name those which were left out. They were Hertford, Middlesex, Surrey, Sussex, Dorset, Devon, Cornwall, North Wales, Notts, Derby, Westmoreland, Cumberland, Durham, and Northumberland. "And furthermore be it enacted, that if in any of the said drifts, there shall be found any mare, filly foal or gelding that then shall be thought not to be able nor like to grow to be able to bear foals of reasonable stature, or not able or like to grow to be able to do profitable labours, by the discretion of the drivers aforesaid or of the more number of them, then the same driver or drivers shall cause the same unprofitable beasts, and every of them to be killed, and the bodies of them to be buried in the ground or otherwise bestowed, as no annoyance thereby shall come or grow to the people, there near inhabiting or thither resorting."[2]

[1] *Ibid.*, p. 24.
[2] *Ibid.*, p. 24.

It will be noticed that the parts of the country which Henry intended should raise heavy horses for war coincide closely with those which now raise heavy horses for draught.

In spite of the efforts of so many governments, however, the great horse was never the only horse in the country. There were still many of the older and smaller kinds. Thomas Blundeville, who wrote in Elizabeth's reign, tells us that " Some men have a breed of Great Horses, meete for warre and to serve in the field. Others have ambling horses of a meane stature for to journey and travel by the waie. Some again have a race of swift runners to run for wagers or to gallop the bucke. But plane country men have a breed only for draftes or burden."[1]

Thus, races of a casual kind were run even in Elizabeth's time, and, though Blundeville tells us that " the Turk, the Barbarian, the Sardinian, the Napolitan, the Jennet of Spaine " and others had been imported and had prospered " verie well in this lande,"[2] yet Gervase Markham maintains that the native horses were still the swifter : " Againe for swiftnesse, what Nation hath brought forth that horse, which hath exceeded the English ? For thereof we have this example : when the best Barbaries that ever were in my remembrance were in their prime, I sawe them over runne by a blacke Hobbie at Salisburie of Maister Carltons, and yet that Hobbie was more over runne by a horse of Maister Blackstone called 'Valentine,' which 'Valentine' neither in hunting nor running was ever equalled, yet was a plaine bredde English horse both by syre and damme."[3]

The establishment of modern racing and breeding of horses for racing only was chiefly due to the Stuarts, for James set up regular courses at Newmarket, where he often resided, and, by buying from John Markham, a merchant, what was probably the first Arabian horse to come to England[4] and giving no less than £154 for him, set his son and grandson the example of importing horses of eastern blood. The transaction is thus entered in the books of Buckingham,

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[1] *Ibid.*, p. 31.
[2] Ridgeway, p. 377.
[3] *Ibid.*, p. 377.
[4] The General Stud Book, 5th ed., p. 388.

James's Master of the Horse: "Item the 20th of December, 1616, paid to Master Markham for the Arabian Horse for his Majesty's own use, 154 . 0 . 0*l*."[1]

In the light of Gervase Markham's opinion about "the best Barbaries that ever were in his remembrance," James's Arab seems just the kind of beast to have taken the fancy of "the wisest fool in Christendom," for the Duke of Newcastle tells us that "being Trained for a Course, when he came to Run, every horse Beat him."[2] Yet there must have been something in those Eastern horses, for, otherwise, breeders would not have continued importing and using them as they did. In the first volume of the fifth edition of "The General Stud Book," a list is given of "Arabians, Barbs, and Turks," which does not include all, beginning with James's Arab and ending with Rumbolt's, imported in 1797. In that list, there are fifty-two Arabians, twenty-two Barbs, twenty-four Turks, one Persian, one Egyptian, and three of unknown origin; and the list states also that "King Charles the Second sent abroad the Master of the Horse, to procure a number of foreign horses and mares for breeding, and the mares brought over by him (as also many of their produce) have since been called Royal Mares. Charles I had at Tutbury, Staffordshire, in 1643, a number of mares and stallions described as race-horses, a list of which from the records includes three Morocco mares."[3]

Why such a persistent importation of horses which were not faster, as a rule, than those already in the country? There can be only one answer, namely, that they were brought in for crossing and that, among their descendants, horses were found faster than their parents on either side. Many English horses were big and strong, up to fourteen and fifteen hands, or even more, but they were of mixed descent and, therefore, not all heavy horses. The imported horses, even in Blundeville's time, were of very different type: "Those horses that we commonlie call Barbarians, do come out of the King of Tunnis land, out of Massilie Numidia, which for the most part be but little horses, but therewith verie swift,

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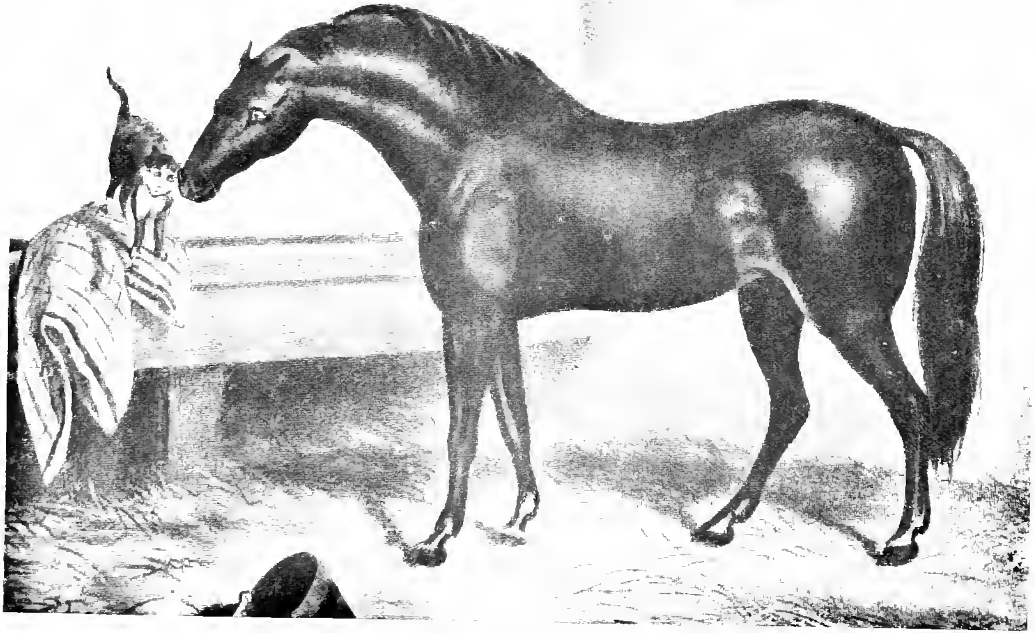
[1] Ridgeway, p. 379.
[2] *Ibid.*, p. 377.
[3] General Stud Book, 5th ed., vol i., p. 388.



THE GODOLPHIN ARABIAN

From Sir H. de Trafford's "Horses of the British Empire."

and able to make a verie long cariere, which is the cause why we esteeme them so much."[1] The horses which " come from Turkey, as well into Italie, as hitherto into England, be indifferentlie faire to the eie, though not verie great nor stronglie made, yet very light and swift in their running, and of great courage." Obviously the Thoroughbred is a compound of the size and strength of the English horse with the lightness and courage of the " Arabians, Barbs, and Turks."

It was not long however till the Great War Horse was overthrown by gunpowder and Cromwell's Ironsides and transferred to a humbler but safer occupation. England was growing in wealth and population. Trade and commerce were flourishing, older industries, like wool, expanding, and younger ones connected with iron and coal drawing people into districts which, hitherto, had been but thinly populated. The positions of Bristol and Norwich as next in size to London were being threatened by what had been little towns and villages in the north. More and more food was demanded, and the country was doing its best to produce it. Most of the land which had fallen back into grazing after the Black Death was tilled again, and the plough was being pushed into places which never had been tilled before. Charles I had brought Vermuyden from Holland to drain the fens ; and moors and bogs, heaths and wastes were being reclaimed, from one end of the country to the other. At the very opening of the war which was to bring about the downfall of the Great War Horse, turnips and red clover were introduced from the Low Countries by Sir Richard Weston, and, though unsuccessful for a time, these crops had only to wait till Tull had shown the advantages of thorough cultivation and drill sowing to break down the old three-field system and, taking their places in the new four-course rotation, become the starting-point of modern farming. In the position thus established, work was found for the discharged war horse between the chains of the plough and the shafts of the waggon.

At the same time, larger and stronger cattle were wanted for the plough and were found where Weston found turnips and red clover. They were brought mostly to the east of

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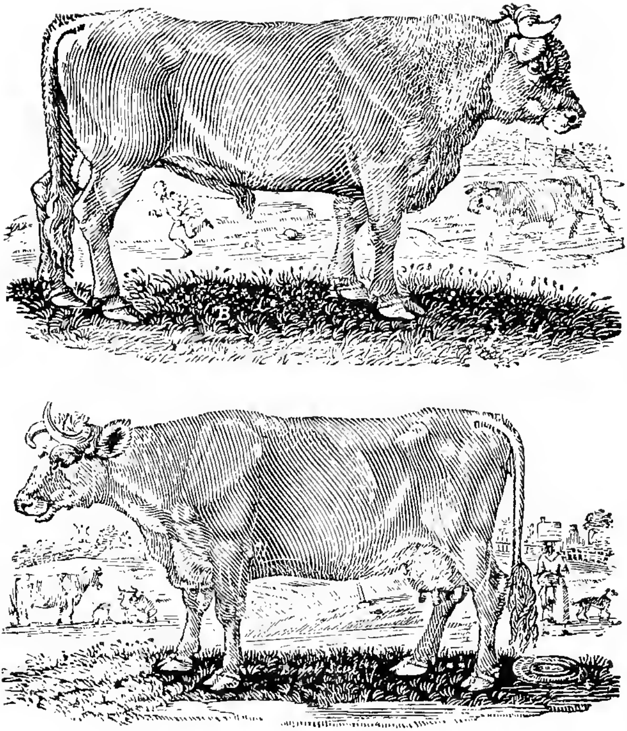
[1] Ridgeway, p. 377.

England, from Durham and Yorkshire southwards. The modern Shorthorns are their direct descendants. But these large cattle were scarcely imported when they were diverted to another purpose. Till the eighteenth century, little beef was consumed, and the supply came from worn-out cows and old bullocks. For this there were two main reasons: the poverty of the population and the lack of winter feeding for stock. Beef could be fattened only on the summer pastures, and what was to be consumed in winter had to be killed and salted down in autumn. Only cows and working bullocks and a minimum of young stock were carried over the winter; but, as the population grew wealthier, the demand increased, and, by growing more and more turnips, farmers were able to winter larger numbers of young stock, and, so, have more cattle for beef. In the nineteenth century, after the introduction of linseed cake and other feeding stuffs, stock of all kinds could be fattened throughout the year.

So far we have said little about other stock than cattle and horses. References are to found to the importation of sheep in the eighteenth century and to pigs later, but they are vague and indefinite. All that can be said is that new kinds must have been brought in by most of the invading peoples, and, though there may have been no thought of altering or improving the stocks in the country, it is scarcely possible that the long period in which wool was the chief export and merchants were in close touch with the continent can have passed without importation of better-woolled sheep from Flanders or Spain.



THE HOLSTEIN, OR DUTCH BREED
From Bewick's "British Quadrupeds"

CHAPTER II

THE EARLY BREEDERS AND THEIR METHODS

IF two varieties of animals interbreed for a few generations, new kinds are produced which differ from each other and from either parent variety. But few, if any, new characters appear, for those borne by the new generations—colours, flecks, length of limb, size of body, and so on—are merely those borne by the original varieties shuffled and reshuffled into new combinations. If the interbreeding of two varieties produce new kinds, the interbreeding of more than two varieties must produce many more, and the new generations must be highly mongrel. Let us see how new varieties have been produced among domestic animals and find, if possible, the methods adopted by stock breeders to render the favoured ones constant and true.

Till the Norman Conquest, no stock, excepting, perhaps, the Roman cattle were imported with the definite purpose of improving those already in the country, but, merely because they were males, the "stallions of great value" which Shrewsbury obtained leave from the Conqueror to import, the hundred "stallions of large stature" imported by King John, and the "Arabians, Barbs, and Turks" imported in the seventeenth and eighteenth centuries were intended to improve the horses of the country. The object of the importers was to produce stock like those they had imported, and their action is to be explained on no other ground than that they expected the imported to leave stock not unlike themselves: that horses of large stature would leave horses of large stature, and swift horses swift horses. The acts of Henry VII and Henry VIII were inspired by the same belief: that horses would get horses and ponies ponies.

Like many others, however, this belief, though assured of permanence by being described in the three words "like begets like" and the action it dictated being described with equal terseness in the five words "put the best to the best," had to submit to modification. Even among early race-horse breeders, a sire's prospective value at the stud was measured by his success on the racecourse. The fastest horses commanded the highest fees, while, if they were not destroyed, those which had not been successful were either put to some ignoble work or "to serve country mares." But neither the successes nor the failures bred all as expected.

Flying Childers, foaled in 1715, was "generally supposed to have been the fleetest horse that was ever trained in this or any other country,"[1] yet Mr. Charles Richardson, a competent modern authority, remarks that "it is curious that he should not have done better at the stud."[2] Bartlet's Childers, his brother, was never trained, yet he "got so many good horses that he is now justly ranked with the first-rate stallions"; [3] and Jigg and his son, Partner, were both used as common stallions till their value was revealed through their progeny. But the most notable of all successful failures was Bartlet's Childers's grandson, Marske, who was foaled in 1750 and exchanged by his breeder, Mr. Hutton, for a chestnut Arabian belonging to the Duke of Cumberland. He was twice successful in 1754 and beaten three times next year. He then went to the stud and at the Duke's sale (in 1766 ?), was sold for a small sum to a farmer, for whom he covered country mares in Dorsetshire at a fee of half a guinea. At the same time, Marske's son, Eclipse, which had been foaled in 1764 and is still the most famous of all race horses, was sold to Mr. Wildman, a Smithfield salesman, who afterwards sold him to Mr. O'Kelly, by whom he was raced.[4] When Eclipse's superlative powers had been disclosed, Mr. Wildman bought his sire Marske from the farmer who was using him in Dorsetshire who, "according to Pick," "was highly pleased with having got rid of what he thought was a bad bargain."[5] With Wildman, Marske's fee "rose to three, five, ten, and thirty guineas in a few years."[1] Subsequently he was sold to Lord Abingdon for a thousand guineas, and stood at Rycot, in Oxfordshire, at a hundred guineas, the first stallion to command a three figure fee.[2] Thus the belief that like begets like was modified and supplemented by the belief in the tried and tested sire.

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[1] The General Stud Book, 5th ed., vol. i, p. 379.
[2] Richardson's "New Book of the Horse," p. 35.
[3] Stud Book, vol. i, p. 379.
[4] Low's "Domesticated Animals," p. 52b.
[5] "New Book of the Horse," p. 37.

Robert Bakewell, the greatest of all stockbreeders, was the son of the farmer of Dishley, in Leicestershire, where he was born in 1726 and died in 1795. His father, who was one of the foremost farmers of his time, died in 1773, at the age of 88, but, while still young, the son was encouraged to make journeys to distant parts of the country and, when he was old enough to become the more active partner, was unusually well equipped in experience and knowledge. He was one of the first to see the growing demand for beef and mutton and go out of his way to meet it. Here and there in his travels, he had seen a few animals of the kind demanded, and some of these he had brought home to Dishley: a bull from Westmoreland, and heifers from Warwickshire, and sheep from Lincolnshire and elsewhere. He also brought pigs, from whence we know not, and even went as far as Holland for horses. Thus, like the improvers of horses, before him, and also in the belief that like begets like, Bakewell commenced with the best stock he could buy, and, by considering some parts of his operations with sheep and cattle, we shall see whether and how far beliefs or theories which had been acted upon by the horsebreeders were modified or confirmed.

Bakewell's first and most lasting success was with his sheep, but beyond the fact that he purchased here and there such foundation stock as he thought would achieve his purpose: which was to produce sheep carrying a large amount of mutton and a minimum of waste: we know nothing further of his earlier operations. Once his flock was established, however, he started a practice by which his principal method is revealed. Hitherto breeders had been accustomed to sell or exchange with other breeders such of their rams as were good enough for stock purposes, but, in 1760, Bakewell adopted the new plan of letting out his rams for a season. At first this was not very remunerative, for the rams brought him only sixteen shillings a head. But Bakewell persisted, and ten years later they brought an average of ten guineas, while, in 1786, a single ram was let for three hundred guineas. Thus the practice became profitable for Bakewell and, no doubt, for his neighbours, for, in time, there were breeders of Dishley sheep not only in Leicestershire but in other parts of England and even in Ireland. The revelation lies in this, however, that, since the rams which had been let were still his property, Bakewell could bring back those which had done best in other flocks for use at home and, so, retain for his own flock the most successful sires of the breed. Thus Dishley-bred sires could be brought back again to Dishley, after having been tested in other flocks.

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[1] *Ibid.*, p. 37.
[2] *Ibid.*, p. 37

This practice entailed a result which was viewed with great misgiving, not by Bakewell himself, perhaps, but by other breeders. Because no new stock had been added since its foundation and Bakewell's rams were always of his own breeding, the Dishley flock and all other New Leicester flocks —as they were called—which depended upon the Dishley flock for breeding stock were excessively inbred. There had been some inbreeding, which still continued, in the production of the racehorse—Spanker himself, for instance, a horse bred about 1660, and his daughter out of his own dam were two of the eight great-grandparents of Flying and Bartlet's Childers—but this was probably unknown, and the only argument in its favour was the continued excellence of Bakewell's stock. The chief arguments against it were that it produced weaker stock, that it was contrary to nature, and that it was irreligious. But Bakewell's stock were neither weaker nor smaller. They may have seemed smaller, but that was because they were rounder and tighter than other stock, and the hooks and angles and big bellies which were so common at that time had been eliminated. Nor is it against nature, for, at all times, among polygamous animals, the strongest male has continued to be master of the herd or flock till killed or driven off by a stronger, which is often a younger brother or an elder son. Nor does any religion give serious attention to the lower animals in the management of their affairs.

In Bakewell's time the cattle of the English midlands were descended from every kind which had come to Britain, with the exception of the Norse which were still restricted to the coasts. Their colours and colour patterns varied like those of a menagerie; the full size of the Dutch had been imparted to many, and many also carried the long, wavy, horns which had come in with the Romans. So, they were generally called Longhorns. The best of their kind for his purpose were found by Bakewell in the hands of Mr. Webster of Canley, near Coventry, whose stock had come from those of Sir Thomas Gresley, near Burton-upon-Trent. Somewhere between 1750 and 1760, Bakewell brought two Canley heifers and a Westmoreland bull to Dishley, and established his herd by inbreeding from them and their descendants. It is not clear that he intended inbreeding from the start, nor that he adopted it because of any virtue inherent in itself, but rather that, because of his belief in breeding from the best stock and from tested sires, he was forced, no other stock being good enough, to put his own to his own. In so doing, he either followed or initiated a practice which Marshall tells us, in 1784, was then common in Leicestershire: bulls, "if good stock-getters, are kept on so long as they will do business; perhaps till they are ten or twelve years old." Like his rams, Bakewell's bulls were also let out and, so, could be brought back to Dishley. Most of them were kept till old, and his greatest bull, called D, was "twelve or thirteen years old" when Marshall wrote. The diagrammatic pedigree on page 21, which is constructed from the statements of Marshall which follow, will indicate more clearly than words the nature of Bakewell's operations:

"Twopenny, that may be said to have first given the lead to Mr. Bakewell, was out of a cow, purchased, when a heifer, of Mr. Webster, and was got by a bull from Westmoreland."

"D, generally known by the name of the 'mad bull,' is a fine animal; and is a striking proof of the vulgar error, that breeding in and in weakens the breed. He was got by a son of Twopenny, out of a daughter and sister of the same celebrated sire: she being the produce of his own dam.

Nevertheless D is the sire of Shakespear, by another daughter of the same bull, and is probably the most robust individual of the longhorned breed ; while D himself, at the age of twelve or thirteen years, is more active, and higher mettled, than bulls in general are, at three or four years old.

" Shakespear,[1] the best stock-getter, I believe, the midland district ever knew, was got by a grandson of Twopenny (out of a daughter of Twopenny), and a cow of the Canley blood."

From the diagram, p. 21, several inferences are obvious, namely, that Bakewell's first stock bull, the bull from Westmoreland, was at least six or seven years old before he was succeeded by his son Twopenny.

That, no better bull being available, Twopenny is put to his own dam.

That, having a son good enough for stock bull, Twopenny is let to Mr. Fowler of Rollright.

That Son of Twopenny is put to a cow which is both his sister and his aunt.

That, when he was five years old, D must also have been let to Mr. Fowler, and that, at that time, Bakewell must have had another bull good enough (was it Son of Twopenny ?) to be stock bull.

Before we had done with them, we saw that the race-horse breeders had added the belief in the tested sire to the older one that like begets like. To these, Bakewell added another, namely, the belief in inbreeding, which, though it has been consciously avoided, not always successfully, by ordinary breeders, was largely used by the pioneers of nearly every breed and has been more sparingly used, or, at any rate, less strenuously avoided, by the more eminent leaders of later times. Latterly a modified kind of inbreeding, called line breeding, has been frequently adopted, which is neither too weak for the believer in inbreeding nor too strong for the non-believer.

But this last belief was preceded by another which came into vogue with the keeping of pedigrees and the publication of stud books and herd books. The earliest of such books was the " General Stud Book," the first little volume of which appeared in 1793 ; but, though it has long been an

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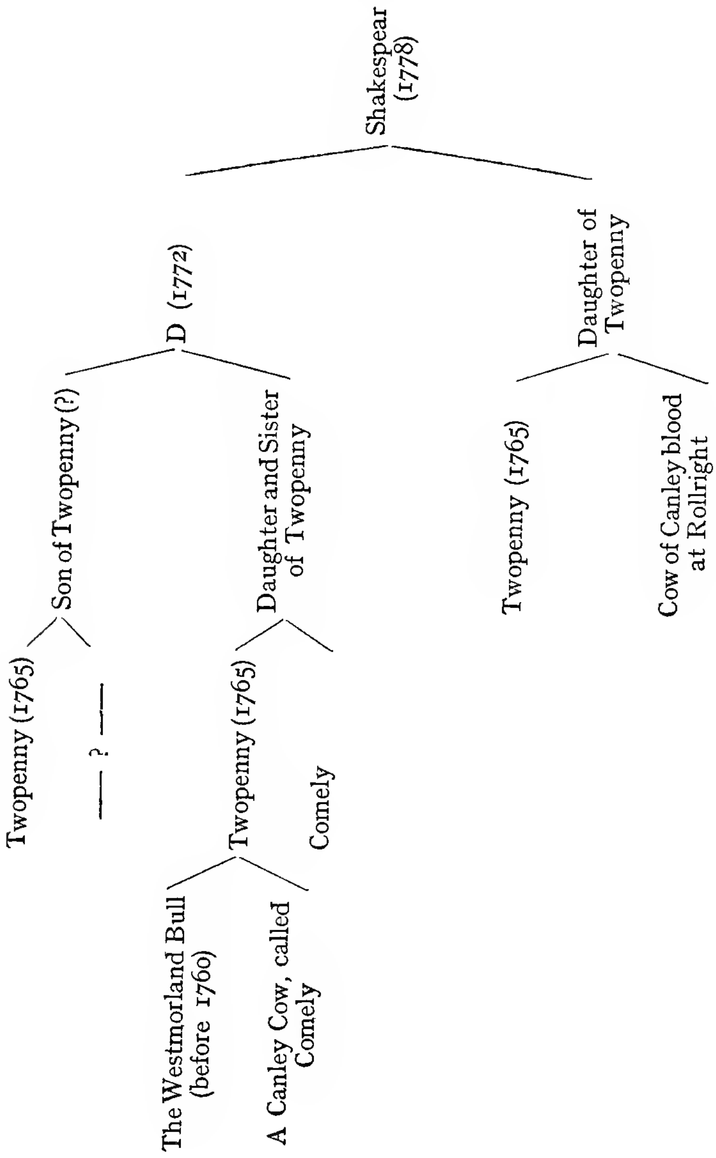
[1] Not bred by Bakewell, but by Mr. Fowler of Rollright.


Shakespear (1778)
D (1772)
Daughter of Twopenny
Son of Twopenny (?)
Daughter and Sister of Twopenny
Twopenny (1765)
Cow of Canley blood at Rollright
Twopenny (1765)
?
Twopenny (1765)
Comely
The Westmorland Bull (before 1760)
A Canley Cow, called Comely

annual publication and is now of considerable size, it would be hard to say that it has had very strong influence upon the best breeders or the progress of the Thoroughbred. Students of the Stud Book and its pedigrees have looked back to some famous ancestors and have told how the "blood" of some ought to be mixed with the "blood" of others, just as the writers of cookery books tell how certain meals and flours should be mixed with certain spices; but, still, the decision not only as to which animals should go to the stud but also as to which should remain there has remained with the racecourse. A horse which has won the Derby will at once get the offer of good mares, but, if his progeny be unsatisfactory, he may become what the eighteenth century people called "a common stallion." On the other hand, another which has been less successful on the course but has been found to get good stock will bring fame to himself and profit to his owner.

The breeders of Shorthorn cattle, the first volume of whose herdbook was published in 1824, were perhaps the first to be seriously influenced by the remote animals in pedigrees. Though less conspicuous, for there were others before and beside them, the two brothers, Charles and Robert Colling, were to the Shorthorns what Bakewell had been to the Longhorns. Charles, the younger brother, succeeded his father in Ketton, near Darlington, in 1782. Robert, who had been apprenticed to business, joined him, but became tenant of another farm called Barmpton in the following year. Charles paid a long visit to Bakewell in 1783. His first good cow was one called Cherry, which his father had purchased at Yarm, but he added three others in a year or two: Duchess, from Mr. Appleby of Stanwick, in 1784; Lady Maynard,[1] from Mr. Maynard of Eryholme, in 1786; and Haughton, from Mr. Hall of Haughton-le-Skerne, about the same time: and, so, "possessed . . . the best four short-horned cows in existence."[2]

Like Bakewell, Charles Colling began with the best cows he could find, but the bull to be mated with them had to survive so many chances that it is almost a miracle he ever got to Ketton at all. In 1776, a farmer called Hunter retired from farming and sold off all his stock but one cow which he kept because she was a good milker. Having then no land, Hunter grazed the cow in the lanes about Hurworth. In 1777, the cow and her bull calf were sold in Darlington market to a quaker, who resold them, the same day, to Mr. Basnett, a timber merchant. On his way home, Basnett sold the calf to a blacksmith called Natrass. The bull calf was then given by the blacksmith to a young man who had just become his son-in-law, but afterwards he became the property of William Fawcett of Haughton Hill, in whose hands he sired the heifer which Charles Colling bought and called Haughton. He was still alive in 1783, and Charles Colling used to see him as he was going to church. The following Christmas, Robert Colling asked Charles if he knew of a bull for his cows and Robert Waistell's of Elly Hill, and Charles told him of "Fawcett's Little Bull." Charles was asked to buy the bull, and did so for eight guineas. The following summer (1784), Robert Colling told Charles that, having now a bull calf fit for service, Waistell and he had no more need for the little bull, and asked Charles to find them a customer. Charles bought the bull for himself, at the old price, eight guineas. Some time later, Waistell sent a cow to the little bull, but Charles Colling sent back word that the fee was now five guineas.

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[1] Lady Maquard's daughter, Young Strawberry, also went to Ketton, in 1787.

[2] C. J. Bates's "Thomas Bates and the Kirklevington Shorthorns," p. 94.

Whether he was not yet converted to inbreeding or was "discouraged by public opinion running rather on size than quality," Charles sent the bull's daughter, Haughton, to a neighbour's bull, and, in 1787, sold the bull himself to "Mr. Hubback, near Newbiggin, in Northumberland," by whose name, Hubback, the little bull has since been known.

But, if he was afraid of inbreeding in 1787, Colling got over his fear shortly after, for, in a few generations, his cattle were almost as highly inbred as Bakewell's and, perhaps, better. At any rate, they and their relatives had shorter horns, and, so, were in greater demand.

By the end of the eighteenth century, other breeders were eager to possess sons and daughters or grandsons and granddaughters of Colling's famous cows. Colling had sold Hubback, and, by so doing, disparaged him ; so the demand was rather for the cow's descendants than the bull's. When the first generations had died out, the demand was transferred to later generations of the old cows or to closer descendants of such of their daughters or granddaughters as had become famous. Occasionally the immediate descendants of a famous bull were prized as such, but Colling and his contemporaries were no better able than modern breeders to trace back their stock's ancestry in the male line. There are many links by which the memory can trace calves back through their dams for half a dozen generations, but the sires are soon forgotten. So breeders came naturally to lay the greater stress on the female line, and, when pedigrees were printed, with the female line in full and the male line omitted, this natural bias became accentuated, and breeders came to look upon the female as the only line which counts. The descendants of famous cows in the female line are looked upon as those cows' families, but equally famous bulls can have no "families." Apart from the weakness which this inconsistency gives to the ordinary pedigree as a predictive weapon, it is doubtful, as we shall see later, whether even the full pedigree is of consequence beyond the third or fourth generation.

CHAPTER III

HOW BREEDS HAVE BEEN FORMED

IN the previous chapter, we found that stockbreeders have been directed in their work by four main beliefs or theories, each of which, after the first, has been, in some degree, a modification of those in use before it. Stated shortly, in words which merely identify but do not define them, these theories were : 1st, like begets like ; 2nd, the tested sire ; 3rd, inbreeding ; and 4th, pedigree breeding. We are now in a position to discuss the soundness and efficacy of these theories. Half a century ago, an Austrian monk called Mendel made a discovery which lays bare the manner in which plants and animals hand on the characters they bear from one generation to another ; and this discovery can be used not only to explain the theories held by stockbreeders in the past, but to be of assistance to stockbreeders in the future. We shall not drive straight into Mendelism, however, but shall first see how some of the more important breeds were formed ; and, when we are familiar with the experiences of stockbreeders in the past, we shall be all the better able to understand Mendel's discovery and its applications.

What Cadwallader Bates said of the Shorthorn : that it is "to a great extent, a *Bos compositus,*" : might be said of every other breed of British live stock. And the words "to a great extent" need be struck out in only a very few cases. One of the breeds to which they most apply is the Aberdeen Angus, which is composed of selections from half a dozen earlier breeds and races.

We have seen already that the Norsemen brought their cattle to the north-eastern coasts of Scotland. The outstanding features of these cattle were that they were big bellied, short legged, light or silver dun in colour, and hornless.

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We have seen already that the Norsemen brought their cattle to the north-eastern coasts of Scotland. The outstanding features of these cattle were that they were big bellied, short legged, light or silver dun in colour, and hornless.

The Celtic cattle differed essentially from them in being light bodied, long legged, black, and horned. When the two breeds were mated, their crosses were like the Norse parent in being big bellied, short legged and hornless, but like neither parent in colour: being what we now call dun: a colour half way between light dun and black. When the crosses between the two breeds were mated back with the Norse parent, their progeny were Norse in body, length of leg, and hornlessness; but half of them were dun in colour, while the other half were light dun. When the same crosses were mated back to the Celtic parent, half their progeny were Celtic in body, leg, horns, and colour, while the other half were Norse in body, legs, and horn, but dun in colour. Obviously, body, legs, and horns are inherited in one way, colour in another. But, when crosses were mated with crosses, their progeny were a jumble of both parent races as regards body, legs and horns, and another jumble of parents and crosses as regards colour. Three were short legged for one long, three heavy bodied for one light, three hornless for one horned, and one black for two dun for one light dun. Still further; a number of those that were hornless had things called scurs, which are the outer coverings of the horns without the inner cores to stiffen and support them.

These characters were not distributed together, however, the Celtic by themselves and the Norse by themselves: each was distributed by itself, so that—leaving colours aside—an individual might have the legs and body of the Norse with the horns of the Celtic, or the legs and hornlessness of the Norse with the body of the Celtic, and so on in all the possible combinations. Thus, when all those which had inherited the same three characters were grouped together and counted, the different groups in kinds and proportions were as follows:

Hornless heavy short-legged	Hornless heavy long-legged	Hornless light short-legged	Horned heavy short-legged
27	9	9	9

Hornless light long-legged	Horned heavy long-legged	Horned light short-legged	Horned light long-legged
3	3	3	I

It will be noticed that those in the largest group are like the original Norse parents, those in the smallest like the Celtic, and those in the other six groups different combinations of both parent races. If the colours were taken into account, there would be twenty-four different groups in all, for each of the eight groups contained one black beast, for two duns, for one light dun. That is to say, without considering the colours, the interbreeding of the Norse and Celtic cattle produced half a dozen new varieties, considering the colours, twenty-two.

After many years, two new breeds were added to the mixture. About the middle of the eighteenth century, the farmers of the north-east of Scotland adopted "the new agriculture" which had grown out of Jethro Tull's work and required deeper and more thorough cultivation. For this, their Celto-Scandinavian bullocks were too small and feeble, and full-sized cattle were introduced from England: the Longhorns, first, then the Shorthorns, or Teeswaters, as they were then called. In addition to their size, these breeds introduced a number of new characters, the most striking of which were the long horns of the Longhorn and the peculiar colours of both breeds. The Longhorns were of four or five different colours: brown, black, and red, and two varieties of brindle, which were halfway crosses between brown and red on the one hand, and brown and black on the other. Most Longhorns had white stripes along the back and underline. The Shorthorns were mostly red with large white flecks, though, latterly, a few may have been roan and a smaller number white.[1]

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[1] It is not clear when the first mating of the white and the red-and-white ancestors of the Shorthorns took place. It was probably in the latter half of the eighteenth century. Both kinds had been some time in Yorkshire and both had come from the Low Countries. The Shorthorn white is not the same as the wild park "white" which is not a white at all, but a black or red with one very large white fleck.

When these breeds had been interbred with the Celto-Scandinavian mixtures for a generation or two, the varieties produced were well nigh innumerable. There were cattle with horns and scurs of all shapes and sizes and many with no horn at all. Some were large, some small, many neither; some were long legged, some short; some heavy bodied, some light; some wide hooked, some round; and among them were all the original colours—black, light dun, brown, red, and, possibly, white—and every halfway colour which could be produced—brindles of one shade or another between brown and the other three original colours; dun between light dun and black; yellow between light dun and red; and red roans and blue roans between white and red on the one hand and white and black on the other. At the same time, when it was not whole, every colour was broken by longhorn stripes or Shorthorn flecks or both. Here, if ever there was one, was a chance for a Bakewell.

The first reason for the introduction of larger cattle from the south was the production of larger and stronger bullocks for the plough, but such bullocks had scarcely been bred when they were diverted to another purpose, for the southern demand for beef had its effect in the north also. The butchers of London and the growing industrial centres were demanding well fattened carcases, and the farmers of Norfolk and other districts which had first adopted the turnip were already specialising in fattening stock which had been reared by farmers at a distance. As the population grew and the fattening area expanded, the " stores " to be fattened were drawn from farther and farther north, and, eventually from the north-east of Scotland. The butcher preferred a well-fattened carcase, the southern fattener a beast that would fatten evenly and quickly, and the dealers and drovers who carried the cattle south a beast that was hornless to one that was horned. So, the north-eastern breeders set themselves to produce what the butcher, the fattener, and the drover wanted, but followed their own taste in having their cattle black in colour and attractive in appearance. But they did not get everything they desired in a day. They desired, above all, hornlessness, a stout body, a round rump, short legs, and the black colour, and bred more and more from animals having these characters. Yet, even though both parents carried all the desired characters, frequently one or more of the undesired ones—horns or scurs, a light body, the square rump, long legs, flecks and stripes, and the red colour —appeared among their progeny. Sometimes an undesired character would skip a generation or two and reappear again unexpectedly. The colours which produced halfway colours —light dun, brown, and white—and the halfway colours themselves were easily got rid of, simply by not being bred from; but this method did not succeed at once with the disappearing and reappearing characters. Horns were got rid of forty or fifty years ago, scurs later; but long legs, the square rump, the red colour, and white flecks still occasionally reappear, though carried by no parent for many generations. As we shall see later, these skipping characters are not eliminated till those beneath which they lie dormant and hidden are bred pure.

The Bakewell of the north-east of Scotland was Hugh Watson who, when eighteen years old, became tenant of Keillor, in Forfarshire. From his father, who tenanted a neighbouring farm, young Watson received six of his "best and blackest cows, along with a bull, as a nucleus for an Angus doddie[1] herd." Not satisfied with these, however, he "started in the same summer for Trinity Market, Brechin, and purchased the ten best heifers and the best bull he could procure showing the greatest characteristics of the breed." Of these, his son wrote long afterwards: "The heifers were black, brindled, and black with brown muzzles and brown streak along the back. The bull was black, and all black my father stuck to, thus working the other colours out of fashion." While Watson was still young, he visited Robert Colling, hearing about his methods with the Shorthorns and, no doubt, about Bakewell's with the Longhorns. He may not have decided, then, to adopt in-breeding, but he did adopt it by keeping a son of the bull bought at Brechin for his next stock bull, and persisted in it, by having every stock bull for the remaining fifty years of his lifetime succeeded by one or other of his sons. Over all that period, only some half-dozen sires appear in the pedigrees of his best and permanent stock, and these were all kept till old. Others may have been tried, but these were both tried and retained. His most famous bull, "Old Jock," born in 1841, was not sent to the butcher till he was eleven years old, and, on his way there, won the sweepstakes at the Perth show of the Highland and Agricultural Society of Scotland. Watson's method, like Bakewell's, was to select his best young animals for stock bulls and retain those that proved good stockgetters till they were no longer useful or till he had found better. Thus, any of Watson's bulls was put not only to his sisters, but also if she lived long enough to his dam, and, if he lived long enough, to his daughters and grand-daughters. From the diagrammatic pedigree of "Old Jock" on page 31, it will be seen that, because of the inbreeding, he has only six ancestors in the sixth generation backwards, whereas, had there been no inbreeding, he would have had sixty-four.

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[1] Angus means Forfarshire; doddie and dodded are the local noun and adjective for polled or hornless cattle. Hummel, a Scandinavian word, is the Aberdeenshire equivalent.

First, by success at local shows and, later, at those of the Smithfield Club and the Highland and Agricultural Society of Scotland, Watson made his cattle known as the best in the country; and Keillor became the chief centre for stock bulls for the best of the other breeders who, in turn, supplied breeders of a lower grade. Thus, before he was middle aged, the greater part of the polled black cattle of Forfarshire and Kincardinshire were descended from Watson's stock. Between 1840 and 1850, McCombie, of Tillyfour, the leader of the Aberdeenshire breeders, whose aims were the same as those of Forfarshire, secured a number of Watson's stock, and, through them and their descendants, the Keillor "blood" was carried to all parts of Aberdeenshire and Banffshire. And, before McCombie had gone, a third leader, Sir George Macpherson Grant, of Ballindalloch, in Banffshire, had arisen who, with stock descended from Keillor and Tillyfour, carried the work of Watson and McCombie down to the present century. Thus, at the present day, there is no animal in the herdbook of the Aberdeen-Angus breed—as the north-eastern cattle came to be called—which is not descended many times over from the stock with which Hugh Watson started at Keillor in 1808.

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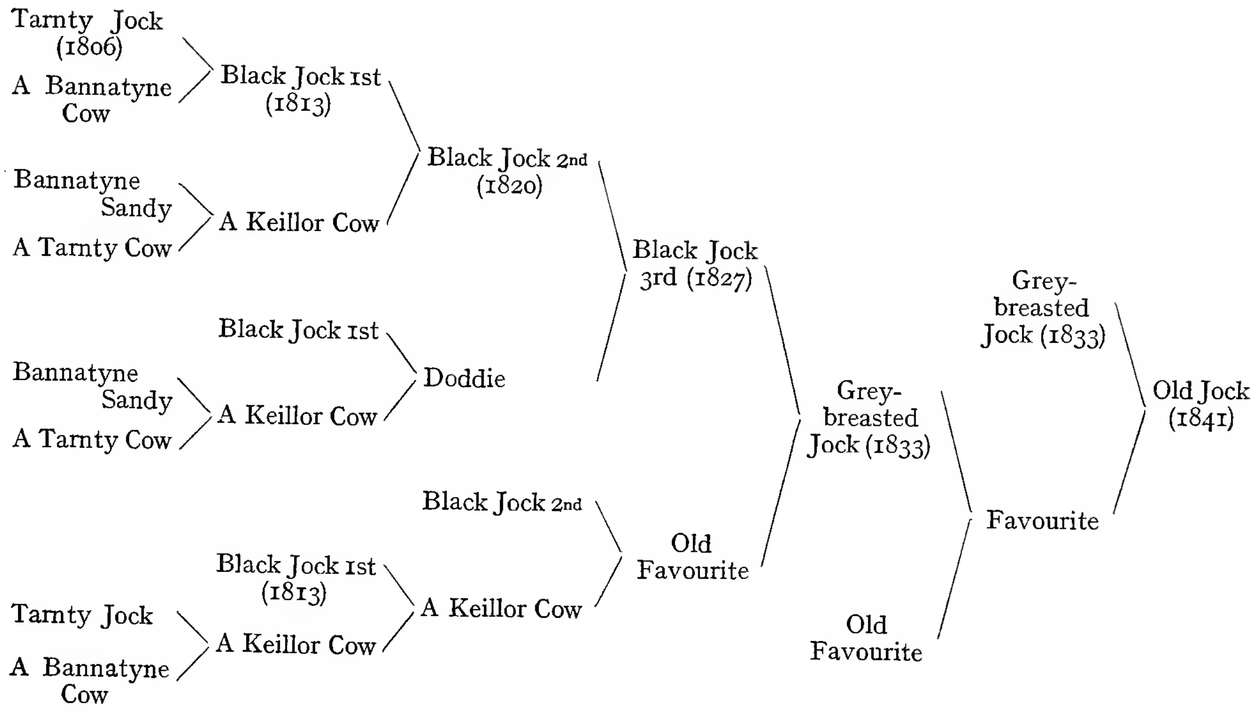
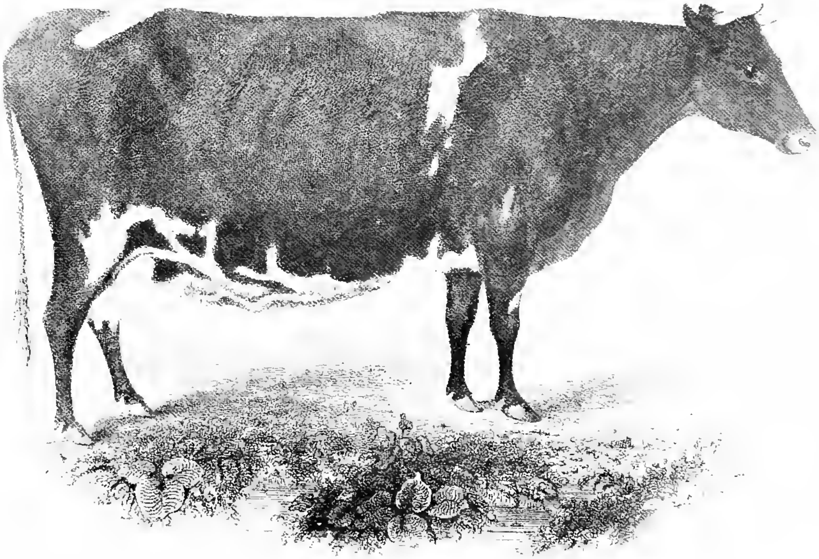

Tarnty Jock (1806)
A Bannatyne Cow
Bannatyne Sandy
A Tarnty Cow
Bannatyne Sandy
A Tarnty Cow
Tarnty Jock
A Bannatyne Cow
Black Jock 1st (1813)
A Keillor Cow
Black Jock 1st
A Keillor Cow
Black Jock 1st (1813)
A Keillor Cow
Black Jock 2nd (1820)
Doddie
Black Jock 2nd
A Keillor Cow
Black Jock 3rd (1827)
Old Favourite
Grey-breasted Jock (1833)
Old Favourite
Grey-breasted Jock (1833)
Favourite
Old Jock (1841)

So has it been with all other breeds. Impelled by economic causes, but allowing their own fancies and tastes to have what effect they pleased in such matters as horns, colours, markings, and so on, the breeders in a district selected from the many varieties to their hand the stock which seemed best to them for the production of beef or milk or both, and continued to breed from the type which pleased and paid them best. In some districts, as in Ayrshire, whose breed is largely descended from the same stock as the Shorthorns, the native stock were neglected ; in others, as in Sussex, North Devon, Wales and Kerry, the natives were favoured ; but, in all cases, the modern breed is indebted, in higher or lower degree, to the stock which were in the district to which it belongs at the end of the eighteenth century.

It has been different with breeds of sheep, which are indebted to the eighteenth century natives of their own districts in only a few cases. Bakewell's breed, the Leicesters, were so superior to all others that they were soon carried to many other districts. In Northumberland and the south-east of Scotland, the Leicester has remained pure and uncrossed, but the breeders, with tastes which were different from those of Leicestershire, have handed down a breed, called the Border Leicester, which is longer in the leg and more attractive in appearance than the original Leicester. Elsewhere the Leicester was used for crossing and grading the native sheep, and this was so persisted in that we have now six modern breeds which resemble the original Leicester in size, wool, and ability to fatten, namely, the Wensleydale or Yorkshire Leicester, the Lincoln, the Cotswold, the Devon, the Romney Marsh, and the Roscommon Longwools.

About thirty years after Bakewell started his work among the longwools, Robert Ellman, of Glynde, near Lewes, in Sussex, began work of a similar nature among the short-wooled sheep of the South Downs. His methods were like Bakewell's, excepting that the stock from which he bred were all found in his own district and his inbreeding was less intensive. The Sussex sheep of Ellman's young days are described as " of the smaller breeds of Sheep, with light fore-quarters, narrow chests, long necks, and long, though



AYRSHIRE COW

From Howe's "British Domestic Animals"

not coarse, limbs. The wool was short, fine, and curling."[1] In a few generations, this sheep had still the same kind of wool, though in greater quantity, but, otherwise, was transformed by Ellman into the most symmetrical animal of its kind in Britain. The legs were short, the chest and back broad, the body round and full, and capable of carrying an even covering of mutton.

Like the Leicesters, the South Downs were also used for crossing and grading the sheep of other districts, from the result of which we now have three other shortwooled breeds: the Hampshires, the Shropshires, and the Suffolks, and still another breed, the Oxford Downs, developed from crosses between the Hampshires and the Cotswolds.

Though the Leicester can be traced in some and the South Downs in others, the remaining breeds of the country, which are mountain or half-mountain breeds, are all chiefly descended from the stock which were in their districts in the end of the eighteenth century.

Though sheepbreeders have had less trouble than cattle-breeders with disappearing and re-appearing characters, nearly every breed has been troubled with black wool and hairs or kemp among the wool, and breeds with coloured legs and faces have often been affected with a larger degree of mottling or speckling than the breeders desired. In many breeds, horns have been troublesome by lacking size in breeds which should have them large and by being present as mere stumps or even as scurf in breeds which should not have them at all. And horns will continue to be troublesome till we know more about them. They are more complicated than cattle horns, for, to have clean heads in cattle, only the causes which produce the core and its covering have to be eliminated, whereas, in sheep, if there be only one cause for the core, there are more than one affecting the horny covering, and these affect not only the size of the horn, from the full horn of the Blackface to the stump of the Cheviot or Herdwick, but also the kind and quantity of the scurf which is frequently found upon the heads of so-called hornless breeds. Besides, these causes produce greater effects in the ram than in the ewe, and we do not yet know the sizes and conditions of horns in the ewe which correspond to the parallel sizes and conditions in the ram.

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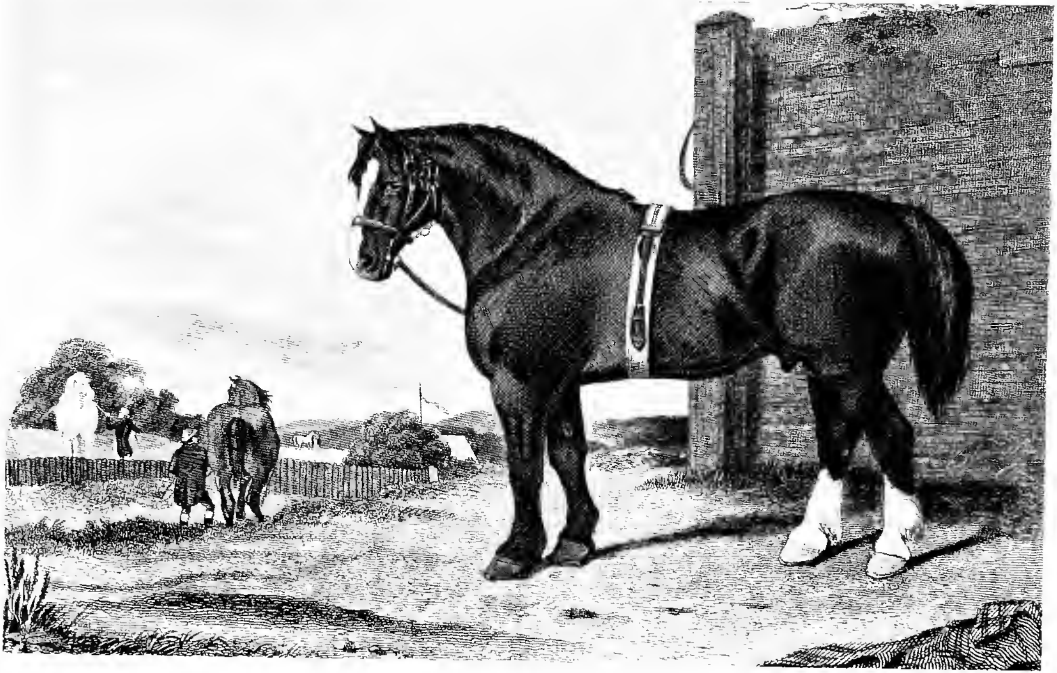
[1] Low's "Domesticated Animals" p 162.

So many jobs can be found for a horse, that the misfits, which are horses that do not grow up as their breeders intended, can usually be fitted in somewhere. The horse which is a misfit for the railway lorry may be a fit for the light waggon; he that fails to be a hunter may qualify for riding or driving or even be useful in the plough; the little beast that is too light for the plough may be smart enough for a light trap or strong enough for the coal pit, and so on. For this reason, a great many horses are bred on the chance that they may be one thing, but on the certainty that, if they be not that one thing, they must be something else. Medium-sized farm mares are put to a thoroughbred one year, a cart horse the next; large ponies are put to an Arab or a Hackney at one time, to one of their own kind at another. Thus, the greater number of the horses in the United Kingdom are of mixed descent and the smaller number, chiefly the racehorse and the draught horses, are bred for one specific purpose only.

As has been said already, the draught horse is the descendant of the great war horse which, when it was discarded by the soldier, was turned over to the farmer and the waggoner. For a time, some were used in family coaches and the predecessors of the stage, but this occupation failed them when McAdam made the roads smoother and firmer. In parts of the country, others were used as pack horses, but this occupation also failed when it was found that a road which went round the hill was better than a track which went over. Thus, while the roadmakers were decreasing the need for the lighter descendants of the great horse, the expansion of the tillage area, with deeper and more thorough cultivation, was increasing the need for the heavier ones, and, by persistently breeding from the strongest and heaviest of the horses in their several districts, sometimes with horses from elsewhere, the farmers of England and Scotland have produced us the Shires, the Suffolks, and the Clydesdales, but, with studs that were small and sires not bred by themselves, these farmers have not been inbreeders, excepting unintentionally, when a sire which was new to the district happened



DRAUGHT STALLION
From Stephens' "Book of the Farm"

to be related to a former without the farmers knowing or even suspecting. Nor has the rule of the tested sire, whether good or bad, been followed as closely as by cattle and sheep-breeders, for, while a bull or a ram which breeds poor stock usually goes straight to the butcher, a horse with a good show record but a poor stockgetter may pass into several new districts before the farmers in those districts know his performances. Like breeders of other stock, horsebreeders have had troubles with disappearing and reappearing characters. Economically, the most important are size and disease, both of which seem to be as complicated in horses as Galton found stature in man. Frequently ordinary sized horses breed small ones and sometimes abnormally large ones ; and certain diseases have a habit of skipping generations, disappearing and reappearing, in a manner which is very baffling to breeders. The skipping characters about which we know most, however, are among the colours. Sooner or later, among Thoroughbreds, as in most other breeds, a strong dislike arose to grey, but its elimination raised little difficulty, for, so soon as breeders cease to use grey sires and dams, grey disappears. In early days, Clydesdale breeders objected to chestnuts and, long ago, ceased to breed from them ; yet chestnut foals were occasionally born of bay or brown parents not so very many years ago. Black was also objected to for a considerable period, and the number of black foals from bay or brown parents gradually decreased, till the objection was lifted some time ago, and blacks are again increasing. Suffolk breeders had the reverse experience, for they wanted no colour but chestnut, and found, when they bred from chestnuts only, that they got no other colour. The skipping characters (chestnut in horses and red in cattle, for instance) are hard to eliminate but easily bred pure, while those which do not skip (as grey in horses and black in cattle) are easily eliminated but hard to breed pure.

CHAPTER IV

THE JUDGMENT OF MENDELISM

MENDEL reduced both the skipping and non-skipping characters to rule. He also gave them new names which, since they have become universal, we shall have to use. He called the non-skipping characters *dominant*, or masterful, the skipping ones *recessive*, or retiring. It will also be an aid to us, as it was to Mendel, if we sometimes print the dominant characters in capitals and the recessives in ordinary type.

Mendel found that the crosses between dominants and recessives are all like the dominant parent, none like the recessive, but that, when the crosses are mated with each other, the recessives appear among their progeny in definite proportion, namely one recessive to three dominants. He also found, as the breeders of the chestnut Suffolks have found, that all the recessives breed true, but one only in every three dominants. The other two dominants are still crosses, like their parents. This, had they found it, would have been of immeasurable service to Bakewell and his pupils.

For example: If pure-breeding black cattle be mated with red, their crosses are all black, but, if the crosses be mated with each other, their progeny are black and red in the proportion 3 : 1; and all the reds but only a third of the blacks will breed true. Two-thirds of the blacks are still crosses. This may be followed more readily, if set out in tabular form, thus:

Pure Parents = Black x red
Crosses = Black
Crosses' Progeny = 3 Black : 1 red

Namely, 1 black breeding true : 2 black crosses : 1 red breeding true.

But breeds seldom differ in only a single pair of alternative characters. What happens when they differ in more? Aberdeen-Angus cattle are black and hornless, while Herefords are red and horned. When these breeds are mated, their crosses are black and hornless. The red colour and the horns have disappeared, and are, therefore, both recessives or skippers. But, when the crosses are mated, their progeny are of four kinds, namely, black and polled, black and horned, red and polled, and red and horned in the proportion 9 : 3 : 3 : 1. In the first group, only one in nine breeds true, in the second and third, one in three, and, in the fourth, all. This result will also be better followed if set out in tabular form :

	BLACK and POLLED	BLACK and horned	red and POLLED	red and horned.
In proportion =	9	3	3	1
Breeding true =	1 in 9	1 in 3	1 in 3	1 in 1

But the Aberdeen-Angus and the Herefords differ in another pair of characters. The white face of the Hereford is dominant to the coloured face of the Aberdeen-Angus. From these we can see what happens when three pairs of characters are operating. The crosses are white faced, black, and polled, but, when mated with each other, their progeny are of eight different kinds, as follows :

	WHITE faced BLACK POLLED.	WHITE faced BLACK horned	WHITE faced red POLLED.	plain faced BLACK POLLED.
In proportion =	27	9	9	9
Breeding true =	1 in 27	1 in 9	1 in 9	1 in 9

	WHITE faced red horned.	plain faced BLACK horned	plain faced red POLLED	plain faced red horned.
In proportion =	3	3	3	1
Breeding true =	1 in 3	1 in 3	1 in 3	1 in 1

The LAW which brings about these results is that FIRST CROSSES OR HYBRIDS ARE FURNISHED WITH EQUAL NUMBERS OF THE CAUSES OR FACTORS WHICH REPRODUCE THE CHARACTERS THEIR PARENTS CARRIED. For example: the crosses between black and red cattle are furnished with equal numbers of the causes which produce blackness and redness, and, the number of these causes being equal and their distribution to the next generation impartial, each cross's calf may receive a cause for either blackness or redness from one parent and another for either blackness or redness from the other; and the chances are that it will receive from both parents together either BLACK and BLACK causes, or BLACK and red, or red and BLACK, or red and red. This may be clearer in tabular form:

Each calf will receive

	from one cross parent	from the other cross parent
	BLACK	BLACK
or	BLACK	red
or	red	BLACK
or	red	red.

In the first case, the calf is black and pure, and will breed true; in the second and third, it is black, but not pure and will not breed true; in the fourth, it is red pure, and will breed true. From this it follows that, if sufficient calves are bred, the black ones will be to the red as three to one, and only one in every three black ones will breed true.

If the original parents differ in a second pair of characters, say hornlessness and horns, these two characters are distributed impartially, as the black and the red were, among the different varieties of black and red. For example: among the pure black calves, there are one pure for hornlessness, two still hornless crosses, and one horned. This also may be better seen in a diagram in which the initial letters of the factors are printed with the colours distributed perpendicularly, the horns horizontally :

BB PP	Br PP	rB PP	rr PP
BB Ph	Br Ph	rB Ph	rr Ph
BB hP	Br hP	rB hP	rr hP
BB hh	Br hh	rB hh	rr hh

It will be seen that this group of sixteen animals contains four different kinds. The nine in the upper left section are all black and polled, but that in the highest left corner is the only one pure for both colour and hornlessness ; the three in the lower left section are all black and horned, but only that farthest to the left is pure ; the three in the right upper section are all red and polled, but the one at the top is the only one which is pure ; while the single one in the right lower section is pure hornless and red.

The distribution of three or more pairs of characters is too complicated to be shown upon a flat surface.

This short account of Mendel's work may not be grasped at once. In that case, it may be stated that the law has four results which are important for the stockbreeder, namely :

ONE : No new varieties are produced if the original parents differ in one pair of characters only, but two new varieties are produced if they differ in two pairs, six if they differ in three, fourteen if they differ in four, and so on.

TWO : Recessive or skipping characters breed true.

THREE : If the progeny of the crosses carry only one dominant, one in three breeds true ; if they carry two dominants, one in nine ; if three, one in twenty-seven ; if four, one in eighty-one ; and so on.

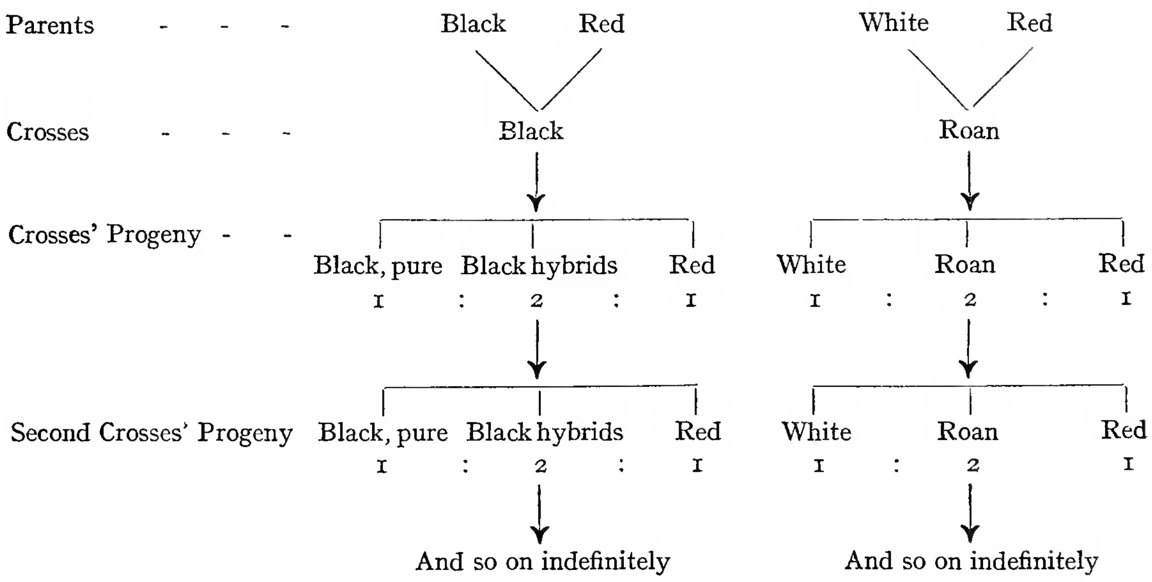
FOUR : If two parents throw a recessive, both are impure.

Since Mendel's time, other discoveries have been made of much less importance, several of which may be mentioned here. In Mendel's experiments, which were carried out with peas, each character alternated or changed places with one other only, and, thus, there were only wrinkled peas and round, constricted pods and plain, and so on. Now we know that any horse or cattle colour may change with four or five others. A chestnut horse may be mated with a pure black, and, black being the dominant, the progeny, though furnished by its parents with the causes to produce both blackness and chestnutness, is black. This black hybrid may then be mated with a pure bay, of which brown is merely a darker shade, and, bay being dominant to both black and chestnut, the progeny, though furnished with the bay cause by its bay parent and either the black or the chestnut cause by its black parent, will be bay. This hybrid bay may, in turn, be mated with a pure dun, and, dun being dominant to bay, black and chestnut, the progeny will be dun furnished with the causes for dun by its dun parent and bay or either black or chestnut, whichever was handed on to the bay by its black parent. Lastly, this dun hybrid may be mated with a pure grey, and, grey being dominant to the other four colours, the progeny will be grey furnished with the causes for grey by its grey parent and dun or whichever of the other three colours was handed on to the dun by its bay parent. A horse may be any one of these five colours, but it cannot carry more than two colour causes at the same time.

Among cattle, there are at least five fundamental colours : black, red, white, light dun, and brown. A black and a red may be mated, and the progeny is a black hybrid furnished with both black and red causes. This black hybrid may then be mated with a white, but the progeny is neither black, nor red, nor white. It is furnished with a white cause by its white parent and with either a black or a red by the black. If furnished with a black cause, it is a blue roan, if with a red cause, it is a red roan. Thus, between black and white, on the one hand, and red and white, on the other, there is no dominance. The effect which either of the two pairs of causes has when furnished in company is halfway between those they have when separate. The two remaining colours behave in a similar manner. Brown produces brindled hybrids with every other colour, while light dun produces dun with black, yellow with brown, and something halfway between itself and white with white.

Though these causes which have halfway effects when together are neither dominant nor recessive to each other, yet otherwise they behave like those which are dominant and recessive. There are three colours among Shorthorns: Red, white, and roan. The reds always breed reds, the whites whites, but, when the two kinds are mated, their produce is roan ; and, when roans are mated with each other, their produce again are whites, roans, and reds in the proportion, 1 : 2 : 1. The whites and the reds breed true, but the roans continue to throw the three kinds, and, so, are hybrids. Thus, like the hybrids between dominants and recessives, these half-way hybrids also throw one of each original parent kind to two like themselves. The behaviour of these two kinds of hybrids is compared on page 42.

Since Mendel's time, it has been shown, as regards both plants and animals, that variations in both quantity and quality are produced by different combinations of different causes or factors, some of which work in the original Mendelian way, some in the new way. The difficulty about these factors is their identification. During the last twenty years, Nilsson Ehle and the other plant breeders at Swalöf in Sweden have raised the productive power of wheat in Sweden by about fifty per cent. This they have done by crossing and recrossing the better and still better varieties from crosses produced with the varieties in their possession towards the end of the nineteenth century. But it is not easy to identify the factors which have been combined in the new varieties. Stronger


Parents - - -
Black
Red
White
Red
Crosses - - -
Black
Roan
Crosses' Progeny - -
Black, pure
Black hybrids
Red
White
Roan
Red
I : 2 : I
I : 2 : I
Second Crosses' Progeny
Black, pure
Black hybrids
Red
White
Roan
Red
I : 2 : I
I : 2 I
And so on indefinitely
And so on indefinitely

tillering power, stiffer straw, better resistance to rust are probably the most important, but it cannot be said that these are all, nor can the effect of any one factor be closely measured.

During a still shorter time, a Danish farmer, Mr. Grut Hansen, has raised the average percentage of fat in his cows' milk from 3.3 to some points over 4 per cent and, at the same time, raised the fat content of his best cows' milk from about 4 to over 5 per cent. This has been done by using in succession four or five tested bulls, that is, bulls which had already been found to leave daughters which gave better milk than their dams. The rise has been gradual both in the general average of the herd and for individual cows, but no definite cause can be identified. The fat-producing glands are more active, no doubt, but what and how many different causes combine to produce the greater glandular activity?

It will not take long now to consider whether the old rules are confirmed or shaken by Mendel's work. These rules are:

1. To breed from stock like those desired: to "put the best to the best."
2. To use tested sires.
3. To breed in-and-in.
4. To breed from pedigree.

The first of these depends upon the opinion that like begets like, and Mendel has shown that this holds only with recessive characters and dominants which are pure. Thus, the older breeders had one supreme difficulty, namely, to find stock which bred true in their characters which were dominants. Southern cattle breeders kept their red breeds red and the Suffolk horsebreeders kept their chestnut breed chestnut without effort, but Aberdeen-Angus breeders found great difficulty in making their breed pure for the black colour, hornlessness, short legs, and the round rump. In such a case, the value of a sire which has been tested and found to breed true is obvious. But where was Hugh Watson, or where was Bakewell, to find young sires carrying the desired characters and as likely to breed true as his own? "There can be only one best breed; and if this be crossed, it must necessarily be with an inferior breed; the necessary result of which must be an adulteration, not an improvement."

Thus, Marshall, the one writer of his time in his confidence, gives Bakewell's reason for in-breeding ; and Mendel's reason is the same. Crossing may be necessary to combine in a set of individuals a number of desired characters, but, when the combination has been effected and the individuals breed true, any further cross must bring in impurities ; and the stock most nearly related to those already produced are the most likely to breed true. If breeds expand and the number of true-breeding stock having the desired characters increases, the need for in-breeding is gone. But the essential words in this statement are " true breeding." If the best animal of the breed does not breed true, and if others which breed true be mated with inferior stock, some of their descendants must be inferior ; and of those which carry the desired characters, some may not be true breeding. In such cases, a pedigree which runs back to famous animals or famous stock may soon become a snare.

To give point to what has been already written in this chapter, we shall consider what happens in a department of stock-breeding which is by no means unimportant, namely, milk production.

In the United Kingdom, there are about four million cows, about half of which, as we shall see later, because their yields are too small, are kept at a loss. Yet the majority of cattle-breeders are careless as to their cows' milk yields. If cattle were bred for beef only, or, if the stock bred for beef were not to affect those which are to produce milk, this carelessness might be excused ; but, as the greater part of the cattle in the country is descended from sires raised in beef herds, the carelessness of the beef breeder is not easily defended. There are, however, breeds in which the milk yield is not considered unimportant and breeders who make strong attempts to improve it. In the past, such breeders have usually been less successful than the beef breeders, chiefly because their cows' yields were seldom measured, not always even guessed. Other things got more attention. If a cow were narrow across the shoulder, lean in the body, had a fine tail and a horn of one or other particular shape, she must be a good milker ! If a bull carried his head high and were stylish in appearance, he must get good milkers !

If a cow's dam, granddam, or some ancestress still more remote were reputed to be a good milker, she also must be a good milker! Whereas a very good milker may be black and hornless and yet have a daughter which is red, horned, and no great milker, and granddaughters, which are like neither their dam nor their granddam. The only test of a cow's yield is the weighing machine, yet even this may not reveal her true capacity, for yield varies with a number of things, of which the most important are age, health, time between calvings, time of calving, and food; and, unless the yield, as given by the balance, be corrected for these causes of variation, the true capacity of the cow may not be known even roughly. Two recent observations get rid of most of the chief causes of variation excepting health. These are that, in the case of a cow in fair condition, the daily yield at the maximum, a few weeks after calving, is about a two-hundredth ($^1/_{200}$) of the yield for a normal year, while the other is that a heifer's yield after her first calf, when she is about two and a half years old, is about two-thirds of what it will be when she is five or six years old. When these bases of correction are used, British cows are found to fall into three rough classes, namely, one giving 1,000 to 1,100 gallons a year (5 to 5½ a day), another giving 600 to 800 a year (3 to 4 a day), and a third giving 350 to 500 a year (1½ to 2½ a day); and it has also been found, though further confirmation of this is still desirable, that, while the highest and lowest grades are the result of separate factors, the middle grade, like the roan of the Shorthorn, is the hybrid between them. Consequently:

	Highest	Middle	Lowest
Highest grade mated with highest produce	all	0	0
,, ,, ,, ,, middle ,,	1	1	0
,, ,, ,, ,, lowest ,,	0	all	0
Middle ,, ,, ,, middle ,,	1	2	1
,, ,, ,, ,, lowest ,,	0	1	1
Lowest ,, ,, ,, lowest ,,	0	0	all

This being so, the breeder's plan is obviously to discard the lowest grades and breed from the others, preferably from highest grades only. Unfortunately, however, the sire's grade is not easily told, for, it will be noticed, by the table above, that, depending upon the sires with which they have been mated, the highest grade dams may throw middle grade calves. Consequently, the only sure plan is to seek out the tested sires. This involves waiting till their daughters have had their first calves, but there is no other way which is certain and sure.

CHAPTER V

THE STOCKFEEDER'S RAW MATERIALS

TILL near the middle of the eighteenth century, farmers had only long fodder—that is natural or meadow hay and the various kinds of straw—with which to feed their live stock in winter. Hay was used, as far as it would go, to young stock. If it were plentiful, working bullocks and heavy-milking cows got a share with their straw, sometimes also a sheaf of unthreshed oats ; but, so soon as they could live upon it till they became actually useful, stock we should now call " stores " got straw alone. Before the end of the century, turnips, clover hay and " seeds " hay, that is hay grown from sown seed, were in fairly common use, and swedes and mangels were becoming known. In some parts of the continent, two other hays, lucerne and sainfoin, were also in use. As yet there were no concentrated foods excepting very small quantities of malt combs, brewers' waste and pulpy oil-press messes which had escaped being used as manures.

In 1804, Dr. Albert Thaer, who had been born heir to a small estate near Celle, in Hanover, in 1752, opened the first agricultural school in Germany. It occurred to him that it would be well for the farmer to know the relative feeding powers of different foods, for, then, when short of one, he could substitute the proper quantity of another. The animals used in his investigations were working bullocks. Thaer first weighed the quantity of food required to keep these bullocks in constant condition while at their normal work, and, then, withholding a definite portion, substituted other foods till he found how much of these were required to replace what had been withheld. A simple example may be imagined. Bullocks perform their normal work and remain in normal condition on a daily ration of, say, 30 pounds of hay. They are divided into four lots. The first gets 30 pounds of hay, the second 20 pounds of hay and 30 of turnips, the third 20 of hay and 40 of turnips, and the fourth 20 of hay and 50 of turnips. All do the same work, but the second lot becomes lean, the fourth fat, while the first and third remain in normal condition. Therefore, forty pounds of turnips have equal effect with ten pounds of hay.

The following table shows the quantities of various roots and long fodders which Thaer found could be substituted for a pound of hay :[1]

	lbs.
Meadow Hay	1.0
Lucerne Hay	.9
Sainfoin Hay	.9
Vetch Hay	.9
Potatoes	2.0
Carrots	2.66
Swedes	3.5
Mangels, with the leaves	4.6
Turnips	5.25
White Cabbages	6.0

Thaer was followed by other investigators, but, unfortunately, their results did not agree too closely. The following, for instance, are the quantities of swedes which Thaer and seven other investigators found equivalent to a pound of hay : 3, 3, 2.5, 3.5, 3.7, 3.5, 2, and 3.5.[2] Had Thaer's successors inquired into the causes of these discrepancies, they might have arrived at uniform results, and farmers would have been using food stuffs with intelligence and economy fifty or sixty years ago. They might have found, for instance, that a stomach which was loaded almost to its full capacity with hay and then asked to deal with half a hundredweight of turnips, in addition, might operate normally neither with the turnips nor the hay, even if the bullock retained his health.

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[1] Boussingfault's "Rural Economy," 2nd ed., p. 549.

[2] *Ibid.*

But the investigators were diverted from the simple path of Thaer by the allurements of chemistry. The newly discovered manures, Chili saltpetre and guano, which both contained a large proportion of nitrogen, were giving marvellous results in crop production. Therefore, nitrogen was the most essential thing in manures! Certain long fodders: clover, lucerne, vetches, and sainfoin: had been found more effective than others, and these contained larger quantities of albumen which, again, contained a large proportion of nitrogen. Therefore nitrogen was the most essential thing in foods! This conviction is thus expressed by Boussingault,[1] the great French chemist of the time: "The nutritious principles of plants and their products reside in their azotized"—that is nitrogenized, for nitrogen was then called azote—" principles, and consequently their nutritious powers are in proportion to the quantity of azote they contain."[2] By this time, linseed cake, which was first made in a form to keep and bear transport just after the Brahma press was invented at the end of the eighteenth century, was in common use, and decorticated cotton cake was beginning to make up for time lost in starting. These, by their success as foods and, by being highly albuminous, added strength to the albumen theory. Shrewd farmers had a vague notion that the fats in these cakes were their effective ingredients, but not so the investigators. Did not milk, the first food of all young animals, contain much albumen wherewith were built up their fast growing tissues? Therefore, since nature gave it them, young domestic animals must have much albumen. Did not milking animals give albumen in their milk? Therefore they must have albumen in their food. Did not horses at hard work and athletes in training "break down" muscular tissues? Therefore must the former have oats and the latter beefsteaks. And, though the fattening bullock neither produced milk nor did hard work, yet no reason could be found for giving him different treatment. Tables were drawn up by investigators like Wolff and Kühn to tell the farmers how the rations for their stock should be compounded. The rations for cows in milk, working horses, and fattening bullocks were to contain one part of digestible albumen for every five or six parts of digestible fat (multiplied by 2.5) and digestible carbohydrates added together. Yet, all the while, some British farmers were fattening their bullocks and adding two pounds to their weight a day on rations in which the digestible albumen to the other things was sometimes as wide as 1 in 20 and occasionally narrower than 1 in 4. Clearly, either the investigators or the farmers were wrong.

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[1] "Rural Economy," 2nd ed., p. 521.

[2] Measured by this criterion, decorticated cotton cake should be four times as valuable as maize!

Eventually, however, the advice of the investigators became more reasonable, and, as older workers were succeeded by younger, fell more closely into agreement with the experience of the best stockfeeders. It is not necessary here to do more than give a rough outline of the position as it now stands.

In addition to water and mineral salts, there are three main ingredients in foods: called albumens, fats, and carbohydrates. The white of an egg and the muscle of an animal are albumens combined with a large amount of water. Fats we know. Sugar, starch and the fibrous parts of plants are carbohydrates. Animal rations usually contain all three ingredients, and the mistake of the early investigators was to prescribe for the three working simultaneously before they knew how each worked separately.

When food enters the body, it is first torn and bruised in the mouth, then tossed and mixed in the stomach, and, finally, passed slowly through the intestines. As it passes through, it is attacked by juices and ferments which are produced in the mouth, the stomach, and the intestines. In this attack, a larger or smaller portion of the food is digested or dissolved. This portion is absorbed by the body, the rest is passed out. Thus, by weighing both and subtracting what is passed out from what was taken in, the amount which had been digested can be ascertained. If the body be looked upon as a solid with a drain or canal passing through it from end to end, the undigested food may be looked upon as never having been within the body at all but merely in the canal.

When they have been absorbed, the digested ingredients, now more or less altered, are carried by the blood to the cells of the muscular tissues. Parts of these cells or, at any rate, some of the albumen which has been brought to them by the blood and has become intimately connected with them is constantly combining with oxygen, which has also been carried to them by the blood, and giving off heat, just as coal or any other burnable substance combines with oxygen and gives off heat. With this heat the cells and muscles are kept living and working, and, with the energy obtained from it, the animal moves his limbs and works. This is what is called the "breaking down" of the muscles. Even in starvation this breaking down continues, till the animal dies. If the body absorb more albumen than is necessary to keep the muscles alive and supply such energy as is required for the work the animal performs, the surplus albumen is either used up in the production of energy or stored about the muscles and special places set aside for the purpose, not, however, as albumen but, with the nitrogen and some other elements removed, reduced to fat. In what might be called emergencies, when the animal gets too little food or does more work than usual, this stored up fat may be called upon to unite with oxygen to supply the requited energy. An important example of this is a cow giving more milk than the food she consumes can possibly produce.

The other ingredients of the food, fats, and carbohydrates, cannot "repair" the "brokendown" muscles, because they do not contain nitrogen. They are, therefore, only sources of energy, but, when more is absorbed than is necessary at the time, can also be stored up, both as fat. Thus albumen is necessary to every animal, because every animal is constantly breaking down its albuminous tissues, and still more necessary to those which are growing and those which are giving milk, which contains a large proportion of albumen; but fats and carbohydrates may be used only for the production of energy or the storing up of fat. Indeed, for this purpose, they are more effective and much more economical. Recent investigations, chiefly Kellner's, have shown the relative efficiencies of the chief digested ingredients for the production of energy or fat to be as follows:

Starch	1
Fibre	1.02
Fat in oil seeds and oil cakes	2.41
Fat in grain	2.12
Fat in hay and straw	1.91
Albumen	.94
Cane Sugar	.76

In addition to these ingredients, there is another kind called amides, which may be looked upon as imperfect albumens, of which asparagin and the nitrogeneous substances found in unripe roots are examples. These have not yet been fully investigated, but it may be said that they do not produce fat—nor, presumably, energy—but, in cases, act, to some extent, like albumen, in repairing tissues.

Thus, leaving these imperfect albumens aside, the more modern advice is to give the animal only so much albumen as is necessary for the repair and formation of albuminous tissues and meet the demand for energy and fat with fats and carbohydrates.

But, to make use of this advice, the feeder needs to know:

1. The minimum albumen requirements of the animal, which vary with kind and age and with the purpose for which the animal is being fed.

2. The requirements of the animal in the ingredients which produce only energy and fat. This is expressed in terms of starch and called the "starch equivalent." The feeder multiplies the fat in the foods he proposes to give by the appropriate number—2.41, 2.12, or 1.91—and makes up the remaining requirements with carbohydrates.

3. The composition of the foods he proposes to use, and

4. The proportions of each ingredient which are digestible. And above all, he must take into account the capacity of the animal to deal with large or small quantities of long fodder, roots, or concentrated foodstuffs, for, where large quantities of fibre or roots are fed, the digestibility of these, and therefore of the whole ration, is seriously reduced.

In most books upon feeding, tables are given which tell the requirements of different kinds of stock and the composition and digestibility of the foods in common use. Others indicate how far the digestibility is lowered by fibrous foods. Even with these tables, however, it is not easy for the farmer to follow the advice given him unless he be an expert in juggling with figures.

More recently, another method has been adopted which expresses the needs of animals—and men—in one single statement. A calory (which is spoken of as the small calory) is the name given to the quantity of heat which will raise a gramme of water through one degree centigrade. If burned under circumstances which prevent any of the heat escaping, an ounce of starch will raise about 117 grammes of water through one degree centigrade. Thus, a pound of starch will raise about 1872 (117 × 16) grammes of water through one degree and, so, is said to produce 1872 calories. It has been found that it requires a daily ration equivalent to about seven pounds of starch to maintain a full-grown bullock, neither working nor fattening, but at rest in his stall. Such a bullock, therefore, requires a daily ration which is equal to the production of about 13,000 calories (1872 × 7 = 13,104). During the war, we used to hear that a man at hard work required food to produce somewhere about 4,000 calories in the day. Statements like these are simple enough and easily remembered, but they are not easily made use of by the individual stockfeeder or cook who usually knows some appropriate rations but would be glad to know how much of some other food-stuff should be substituted for one of which he has run short. How different it might have been had the work begun by Thaer been continued!

But work like Thaer's was begun again in Scandinavia nearly half a century ago. Though not absolutely first, the most important was that of Niels Johannes Fjord, who had been teaching in the Veterinary and Agricultural College in Copenhagen since its opening in 1858. Unless that his father was a schoolmaster and small farmer, Fjord was not an agriculturist. Nor was he a chemist. But he was a man of unusual ability and common sense. He chose his father's profession, and, at twenty, passed out of the Training College as "unusually capable." He taught for ten years in Aarhus, and, at a course of lectures on physics there, was discovered by the teacher to be specially gifted in mathematics. The examining professors induced him to become a student at the Copenhagen Polytechnic, and, before he had finished his course, he was appointed lecturer in physics in the college about to be opened.

Fjord was often asked to solve what are called "practical" problems. For instance: the boiler which generated steam to give a bath to horses which were patients in the college was slow in action and greedy of fuel. Fjord devised a new one which acted quickly and economically. Shortly afterwards, he devised a boiler to heat up the milk used in cheese making, and, by this boiler, first became known to farmers, who then asked him to improve their icehouses and to find out whether the old shallow pan could be improved upon for raising cream. In carrying out the latter inquiry, he found it necessary to have many samples of milk tested for the fat they contained, and devised an apparatus, like those perfected later by Babcock and Gerber, which tested a large number of samples at a time. While they were developing their oversea trade in dairy products, it was Fjord the Danes applied to for advice in cooling and refrigerating trains and steamboats.

But the work with which we are immediately concerned was thrust upon Fjord by a serious dispute. In the early eighties, the separator was at work on many Danish farms, and it was asserted that not only the pigs and calves but even the children which were brought up on separated milk were being starved. Fjord was asked to settle the dispute, and he decided to ask the pigs and calves themselves. We shall consider the calves' answer in some detail. On three farms, Fjord selected 32 calves just weaned or about to be weaned from sweet milk. On each farm, these were divided into two equal lots: one to be fed on separated, the other on skim, milk, together with the meal allowance customary on each farm. The first ten days, during which the calves were observed closely to see that their health was good and that they were becoming accustomed to their rations, were not reckoned as part of the experimental period, which lasted from thirty to fifty days, according to the calves' ages. The calves were, of course, weighed: before the experiment began and every ten days afterwards. The data which are pertinent to the result are to be found in the following table :

FARMS	Daily allowance of meals	Daily allowance of skim or separated milk	Percentage of fat in the skim milk	Percentage of fat in the separated milk	Average daily increase of skim milk calves	Average daily increase of separated milk calves
	lbs.	lbs.			lbs.	lbs.
Rosvang	.93[1]	25	.74	.21	1.72	1.55
Sanderumgaard	1.33	20	.49	.09	1.41	1.43
Duelund, first experiment ..	.85[2]	16	.64	.14	1.38	1.10
Duelund, second experiment ..	1.72	20	.65	.15	1.53	1.57

Thus Fjord showed that, when they form part of the usual ration, skim milk and separated milk are not essentially different for calf rearing. A similar experiment with seventy-two young pigs gave a similar result. On the whole, the skim milk calves and pigs did slightly, but only slightly, better than those getting separated milk. There was no starvation, however, and the difference between the two lots was only brought out by the scales.

With the introduction of the separator, many Danish farmers turned over from cheese to butter, that is from a summer to a summer and winter product, and it followed that roots must now be grown to feed the cows in winter and that the pigs must now be fed with separated milk instead of whey. Hitherto pigs had been fed on known quantities of some kind of grain, chiefly barley or rye, and whey. The problem was now : how much separated milk would replace the old quantity of whey ? We do not know in detail how Fjord investigated the problem, but, from later work, we know his method. It was simply to divide the pigs on a number of farms into several lots and, while one lot was fed on the old ration, the others got no whey but different quantities of separated milk till one was found producing the same quantity of bacon as the old ration.

[1] 10 lbs. Danish are equal to about 11 lbs. English.

[2] These lots got less meals and milk than the others, but consumed more hay.

In this work, it was found that six pounds of separated milk substituted, or were equal in feeding power, to twelve pounds of whey.

Once it was begun, however, this kind of work was bound to be continued. Since it had been shown that a pound of separated milk went as far as two of whey, and he had now as much milk as he used to have whey, the farmer could either use more grain and fatten more pigs or reduce his grain consumption and still fatten as many pigs. But, to do this, he must know how much separated milk was equivalent to a pound of grain. The method of investigation was just the same. One lot of pigs was fed with the normal quantities of grain and milk, while a pound of grain was withheld from the other lots and different quantities of separated milk given in its place till one lot, by making the same daily increase in weight, showed that the quantity of milk fed to it was equivalent to the extra pound of grain fed to the normal lot. In these experiments, it was shown that six pounds of separated milk were equivalent in feeding power to a pound of either barley or rye.

In the years 1884 to 1887, Fjord, experimenting with 487 pigs on nine farms, showed that one pound of rye, one pound of barley, six pounds of separated milk, and twelve pounds of whey were equal to each other in feeding value, and could be substituted for each other.

Fjord's investigations into the feeding values of roots were not begun till the winter of 1887–8. These had to be carried out with cows, because very few bullocks are fed in Denmark, and, as cows and their yields are liable to serious variations, and equality in the experimental materials is the prime essential in all experiments, Fjord decided to have the assistance of one who was experienced in cows. To this end, he had a young agriculturist in training for some time, but, unfortunately, this young man died, and Fjord had to carry on the work with the help of the owners of the cows. Just as there had been a prejudice against separated milk for calves and pigs, so was there a prejudice against roots for cows. It was asserted that roots reduced the quality of the milk, that is, reduced the butter fat. Fjord decided to test the truth of this assertion in the first instance, and hoped, in doing so, to gather information which might be useful in future work. The cows at five different farms were divided into two or three equal lots according as the farmer grew both turnips and mangels or either of these roots only. The first lot was to have the old normal ration, namely, definite quantities of concentrates and hay, with as much straw as they cared to eat in addition. The second lot was to have the same ration plus mangels, and the third the same normal ration plus turnips. The following table shows the lots, the rations, and the number of experimental cows on each farm :

FARM	Lot 1	Lot 2	Lot 3	Cows in a lot	Total No. of Cows
Bregentved	Normal ration	Normal plus 36 lbs. mangels	Normal plus 36 lbs. turnips.	12	36
Wedellsborg	do.	do.	do.	10	30
Rosvang	do.	do.	do.	10	30
Sanderumgaard	do.	do. 24 lbs. mangels	—	12	24
Duelund	do.	—	do. 24 lbs. turnips	13	26
					146

The care with which the lots were selected is indicated by the fact that thirty cows at Wedellsborg were drawn from 150. Four weeks were spent in making the selection, in which the cows' ages, time of calving, size, yield, and quality of milk were all observed and taken into consideration before the three lots were finally made up. Even then, the cows were given ten days more to show whether they had become accustomed to the experimental ration. During the preceding month and these ten days, food and milk were measured and analysed, just as during the experimental period, which lasted from February 7th to April 7th, but the figures were not regarded as experimental. As to the question which this investigation was devised to answer, it was found that the addition of roots to the old normal ration did not alter the quality of the milk. The average butter fat found in the milk of the three lots on the farms feeding both mangels and turnips was as follows: Lot 1, 3.33%, lot 2, 3.36%, lot 3, 3.34%.

The figures at Sanderumgaard were 3.59% for both lots and at Duelund 3.35% for both lots.

If extra food be added to a bullock's ration which is already large enough to keep him healthy and active and he consume the whole, there can only be one result: he will lay on more fat. If he do not eat the whole and be allowed to choose what he will eat, then some of the least palatable constituent in the ration will not be consumed. A cow, however, may do one or more of three things, namely give more milk, lay on fat or increase in weight, and leave some of the ration unconsumed. In these experiments of 1887–88, the cows which got roots in addition to the normal ration did all three things: gave more milk, increased in weight, and consumed less straw—the part of the ration in which they were allowed an option—than those getting the normal ration. The latter were slightly under fed, of course. The figures for the three farms feeding both mangels and turnips are as follows:

FARM.	Milk yield per day		
	Normal ration	Normal plus mangels	Normal plus turnips
	lbs.	lbs.	lbs.
Bregentved	20.4	23.3	21.2
Wedellsborg	20.3	22.2	22.1
Rosvang	20.4	23.5	21.6
Average gain	—	2.6	1.3

FARM.	Increase in weight during the period			Straw consumed per day		
	Normal ration	Normal plus mangels	Normal plus turnips	Normal ration	Normal plus mangels	Normal plus turnips
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Bregentved	+38	+68	+48	13.6	11.3	13.0
Wedellsborg	— 7	+29	+ 7	11.3	12.0	11.7
Rosvang	— 8	+21	+21	2.5	2.5	2.3
Average gain	—	31	17	—	.53	.13

As was expected, the investigation of 1887–88 furnished information which would have effect in future work, for, in addition to showing that roots did not alter the quality of the milk, they showed that roots added to the normal ration produced more milk, increased the cows' weight, and saved straw. Beyond this, however, they showed that mangels were a more effective food than turnips, and raised the question: what are their values relatively to each other and to other food stuffs? By this time, Danish farmers were being accustomed to think of relative values, and some of those on whose farms Fjord had been experimenting had shrewd notions as to the relative values of mangels and turnips and grain. In consultations with these farmers, Fjord arrived tentatively at the opinion that a pound of grain was equal to about ten pounds of mangels and twelve of turnips, and he devised an experiment to put this opinion to the test. His method was the same as before. The first lot of cows got the normal ration, but the second lot got two pounds less grain and twenty pounds of mangels on mangel farms and twenty four pounds of turnips on turnip farms, while the third got four pounds less grain and forty pounds of mangels or forty eight pounds of turnips. Thus, if the second and third lots of cows made the same yield of milk, the same rise in weight, and consumed the same quantity of straw as the first lot, Fjord's tentative opinion was sound. As this is the most important experiment we shall have to consider, it will be well to give the rations for each lot of cows at four of the five farms at which the investigation was carried out:

	Lot 1	Lot 2	Lot 3
At BREGENTVED	lbs.	lbs.	lbs.
Corn and Bran	8	6	4
Oilcake	1	1	1
Mangels	0	20	40
Hay	5	5	5
Straw consumed	12.9	13.1	13.1

	Lot 1	Lot 2	Lot 3
At WEDELLSBORG	lbs.	lbs.	lbs.
Corn and Bran	6	5	4
Oilcake	6	5	4
Mangels	0	20	40
Hay	6	6	6
Straw consumed	14.2	14.0	13.0
At ROSVANG			
Corn and Bran	8.5	6.5	4.5
Oilcake	1.5	1.5	1.5
Turnips	0	24	48
Hay	14	14	14
Straw consumed	4.7	5.5	4.8
At SONDER ELKJAER			
Corn and Bran	7.6	5.6	3.6
Oilcake	2.4	2.4	2.4
Turnips	0	24	48
Hay	7	7	7
Straw consumed	14.3	13.3	14.4

In this case the preliminary trials were begun in December on some farms and in January on others. These lasted six weeks on some farms, eight on others, while the real experimental period lasted twelve weeks in some cases, fourteen in others. The results for each farm in detail and for the four farms on the average are as follows :

	Milk yield per day		
	Lot 1	Lot 2	Lot 3
	lbs.	lbs.	lbs.
Bregentved	19.6	19.0	18.8
Wedellsborg	22.8	22.2	22.2
Rosvang	21.3	22.0	21.5
Sonder Elkjaer	21.8	20.7	22.3
Average	21.4	21.0	21.2

	Increase or decrease in weight per day			Straw consumed per day		
	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Bregentved	—.04	—.06	—.13	12.9	13.1	13.1
Wedellsborg	+.57	+1.1	+.65	14.2	14.0	13.0
Rosvang	—.07	—.25	—.08	4.7	5.5	4.8
Sonder Elkjaer ..	—.13	—.10	.00	14.3	13.3	14.4
Average	+.08	+.17	+.18	11.5	11.5	11.3

The three lots of cows are so close in milk yield, rise or fall in weight and in straw consumed, that Fjord was justified in concluding that the opinion that a pound of corn and bran is equal in feeding value to ten pounds of mangels and twelve of turnips was sound. He was not absolutely satisfied, however, for the following winter, 1889-90, he had the experiment repeated on eight farms: with mangels in six cases and turnips in two: the only difference being that in this experiment the turnips were raised from 24 to 25 pounds in lot 2, and from 48 to 50 in lot 3. This small rise indicates the one point in which Fjord was not satisfied. The results were:

	Daily milk yield		
	Lot 1	Lot 2	Lot 3
	lb.	lb.	lb.
On 6 mangel farms	21.1	21.6	21.8
On 6 turnip farms	24.4	25.0	24.5

	Daily rise (+) or fall (—) in weight			Straw consumed		
	Lot 1	Lot 2	Lot 3	Lot 1	Lot 2	Lot 3
	lb.	lb.	lb.	lb	lb.	lb.
On 6 mangel farms ..	+.29	+.34	+.35	14.1	12.8	11.7
On 6 turnip farms ..	—.18	—.12	—.13	6.4	6.4	5.9

It will be noticed that, in this experiment, as in the previous years', the cows on the turnip farms lose weight. This is, probably, because they might have had more food ; but it does not invalidate Fjord's conclusion, for the 25 and 50 pounds of turnips substituted for 2 and 4 pounds of corn and bran withheld from lots 2 and 3 had equal effect with the corn and cake not withdrawn from lot 1. And, since the 20 and 40 pounds of mangels substituted for the 2 and 4 pounds of corn and bran withheld from lots 2 and 3 had also similar effect with the corn and bran not withheld from lot 1, therefore 12½ pounds of turnips=1 pound of corn and bran=10 pounds of mangels.

Unfortunately, this was Fjord's last experiment, for he died after a surgical operation, on January 4, 1891. His work has been continued, however, by successors both in Denmark and Sweden ; and, now, every intelligent Scandinavian farmer buys his cakes and grains and feeds his stock with the assistance of his table, which tells him how much of one food may be substituted for another and helps him to put reasonable money values upon the usual homegrown and imported feeding stuffs. As barley had long been a standard feeding stuff in Denmark, the table shows how much of each of the other usual food stuffs is required to replace a pound of barley, which is taken as the food unit. Such a table, extracted from Professor Nils Hansson's[1] "Handbok i Utfodringslära,"[2] published in 1916, will be found at the end of this volume.

It will be understood, of course, that a table of this kind, in which the figures stand for feeding stuffs of average good quality, must be used with judgment. The value of a feeding cake rises and falls chiefly with its oil content, and the values of all foods, but especially hays and straws, rise and fall with the manner in which they have been saved and stored.

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[1] Director of the Live Stock Experiment Ration, Stockholm.

[2] Handbook of the Science of Stock-feeding.

CHAPTER VI

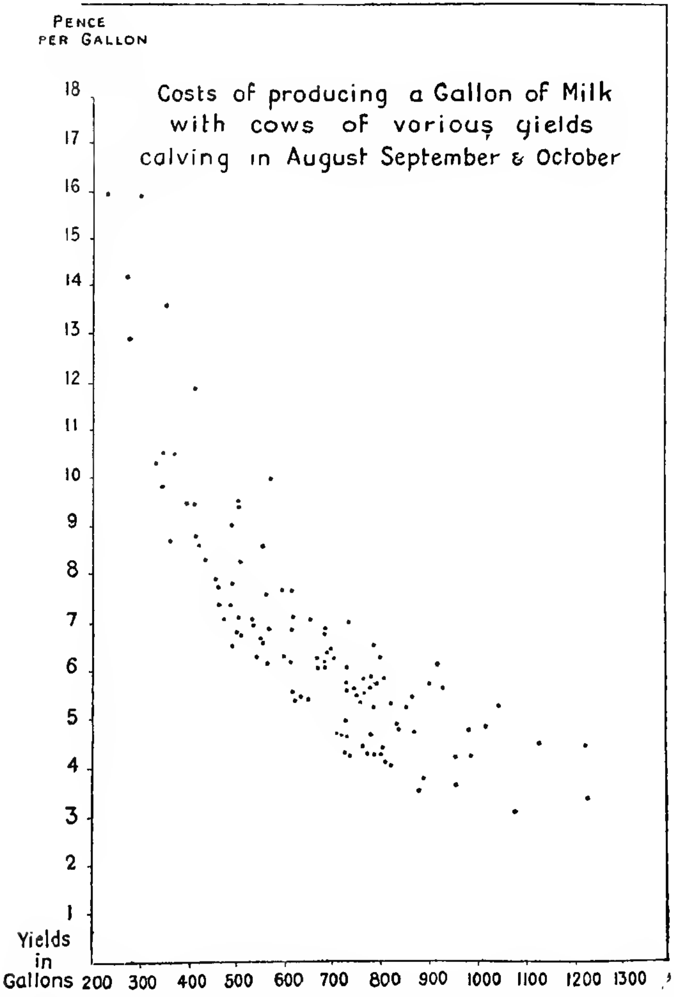
THE ECONOMIC USE OF FEEDING STUFFS

THERE are so many kinds of stock and so many different purposes for which each kind may be raised and fed that it is difficult to speak concisely and yet be sufficiently general about the economic use of feeding stuffs. We shall, therefore, merely indicate the economic use of feeding stuffs in general by considering several cases in which they are used with a clear lack of economy. There are three main causes of ineconomy: first, inefficient stock; second, underfeeding and delay in putting stock to their final purpose; and, third, inappropriate rations.

Unless it be among hens, perhaps the highest proportion of inefficients is to be found among cows. During the four years 1911 to 1915, Dr. Charles Crowther and Dr. A. G. Ruston of the University of Leeds, carried out an investigation on ten farms in Yorkshire as to the "Cost of Food in the Production of Milk." Their method was to keep records of the food consumed by each herd and the milk produced by every individual cow. Bought-in foods were set down at cost prices and home-produced foods at something like an average of the estimates of the farmers whose cows were in the investigation. The cost of the food consumed in producing a gallon of milk on each farm was found by dividing the number of gallons produced into the total cost of the food, while the cost of the food consumed by each individual cow in producing a gallon was found by dividing the average cost of the herd per gallon by the yield of the individual cow and multiplying the result by the average yield of the herd. If, for instance, the average yield in a herd were 600 gallons and the average cost 6d., then the cost for a cow giving only 400 gallons is ninepence:

$$\frac{6\text{d.}}{400} \times 600 = 9\text{d.}$$

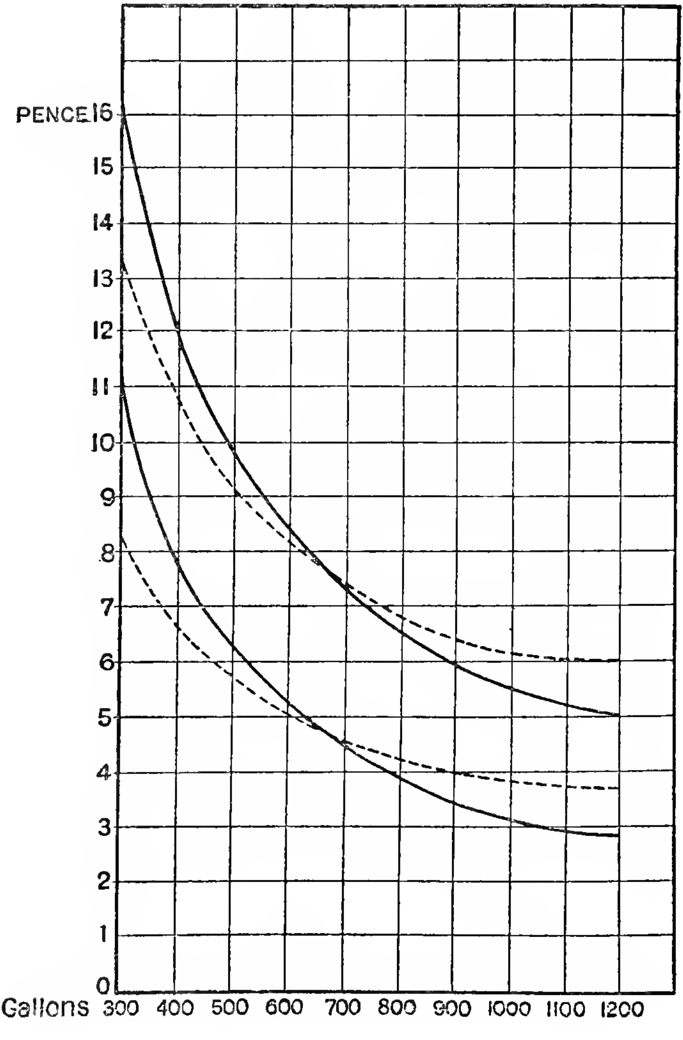
This method does not bring out the true cost of production, however, for it leaves out labour, interest on capital and other



smaller outlays, but, on the other hand, it also leaves out the returns for the calf and manure: and, since these outlays and incomings nearly balance each other, the cost of the food becomes approximately the true cost of production. Even if it did not, the mere cost of the food would serve our purpose, for what is wanted is a comparison of the cost of producing milk by cows of various yields.

When the figures obtained by the Leeds investigation are plotted as in the diagram on page 64 so that the dot for each cow is directly above her yield on the horizontal scale and directly to the right of her cost per gallon on the vertical scale, it will be noticed that the dots for all the cows together —the diagram represents only the cows which calved in August, September and October—fall into a curved figure which shows that the costs of producing a gallon of milk are not the same for cows of equal yields, and that they rise as the cows' yields fall. The cost for the 700 gallon cows, for instance, varies from fourpence to sevenpence a gallon. This is because some of the farmers used cheaper, others much more expensive rations. With the same grade of cow, some produced milk at little more than half what it cost some others.

This diagram does not yet represent the case quite truly, however, but exaggerates the difference between the good and the bad cow. The figures on which it is based were calculated on the assumption that all the cows in the same herd consume about the same quantity of food, but this they do not do. Sometimes a breed is recommended because it can live upon little food, but, if a breed, or an individual cow lives upon little food, then neither the breed nor the cow is a good milker. Recent investigations by Fjord's successors in Sweden, as we shall see later, have shown that, for every additional pound of milk produced, a third of a unit of food must be consumed, that is, a third of a pound of barley, or its equivalent. If two cows otherwise equal give one twenty pounds of milk in the day, the other twenty-one, then the latter will consume an extra third of a pound of barley or its equivalent per day. With this knowledge, the diagram can be corrected. The heavy black lines in the diagram are drawn through the upper and lower boundaries of the curved figure made by plotting the whole of the Leeds data. The dotted are the corrected lines. From these it will be seen that, when milk is selling at sixpence a gallon, cows giving 550 gallons pay their way in the hands of the best farmers, while, in the hands of the worst farmers, cows do not pay their



way till they give 1,100 gallons. These are the crucial yields for the best and worst farmers when prices are as they were before the war. They may vary when prices alter but, however they vary, there is no reason to believe that anything can ever prevent the good farmer being hampered and the poor one impoverished by inefficient cows.

From the mere fact that they are not straight lines, these curves suggest that the better cows not only consume more food but make better use of what they consume. No authority on digestion will allow this, however. What happens is that a portion of the food—we shall see how much later—is used to keep the body alive and in working order, the remainder to produce. Even when idle, neither giving milk, nor fattening, nor nourishing a calf, the cow must be fed. She needs what is called a "maintenance" ration. When working, however—producing milk, fattening, or nourishing a calf—the cow needs extra food commensurate with the extra work. This is called the "production" ration. The maintenance portion of the ration varies slightly with the weight of the cow, but the productive portion is the same for similar yields. A cow giving five gallons of milk needs five times as much production food as a cow giving one; but, as both need near the same quantity of maintenance food, the cost of which is small when spread over five gallons but large when allocated to one, the good cow produces milk at a small cost per gallon, the poor one at a cost which makes her unfit for that purpose. Fifty pounds is an insignificant insurance premium when the income is £1,000, but serious when the income is only £200.

There are many cases of loss from delayed use among horses. The farmer who keeps light mares which are crossed with a Thoroughbred or some horse of like character, in the hope that the progeny will be hunters or pleasure horses of some kind, usually gets no labour from his young stock till they are found to be "misfits" for the purpose for which they were bred. If they turn out fit for hunting or some other pleasure, the price he receives for them makes up for the loss of labour, but, if they are misfits and have eventually to be put to the plough, the labour lost since they were fit for it is not repaid. Perhaps the best example is to be found in the bullock. If a bullock of any of the larger breeds or a cross between any of those breeds and an ordinary cow be fairly well fed and cared for from birth onwards, he increases in weight at the rate of about two pounds a day till he is about two years old : after which the daily increase declines slowly till, when he is between three and four years old, it is nothing at all. Clearly, this bullock must be kept at a loss after some time in his third year, and, unless the food he consumes declines as his daily increase in weight declines, must be kept at a falling profit just after he is about two years old. Most of the bullocks reared and treated in this way are sent to the butcher when they are between eighteen and twenty seven months. Such bullocks are usually suckled singly, or with another calf, by their own dams ; and, though this system involves the minimum of labour and trouble and rears the best calves, it is doubtful whether it is as profitable as having the dam milked and the fat which is taken from the milk and made into butter replaced by fats from cheaper sources. There is undoubted waste of energy in having cows capable of yielding eight hundred or a thousand gallons of milk in the year followed by one or perhaps a couple of calves for nine or ten months. On such cows, Hugh Watson reared four, sometimes five, calves : two during winter and spring, two others in summer, and still another in autumn.

But the majority of the calves which are eventually to be fattened for the butcher are not so well reared. They are reared upon skimmed or separated milk alone, or upon milk and meal or grain, and their progress depends upon the quantity and quality of both liquid and solid foods. Skim milk contains about four per cent of albumen and rather more sugar. Two gallons contain more than enough albumen to produce new and repair the " broken down " tissue in a young calf, but the surplus albumen and the sugar are much less effective than the fat which has been removed would have been for the production and storing of fat. Consequently a calf reared on skim milk is seldom fat and, because it has too little albumen left, when some of that in the food has been asked to do the work the fat would have done, frequently undergrown. If ground grain and meals be added to the albumen, the calf converts the fats and starches he can digest from them into energy and stored up fat, and, since fat is the more effective, the calf's progress will depend largely upon the fat content of the meals and grain and upon the quantity he is able or is allowed to consume. But artificially fed calves are seldom given as much of all kinds of foods combined as the naturally fed calf draws from its dam, with the result that they are usually both leaner and smaller, and are therefore older till they are fit for the butcher.

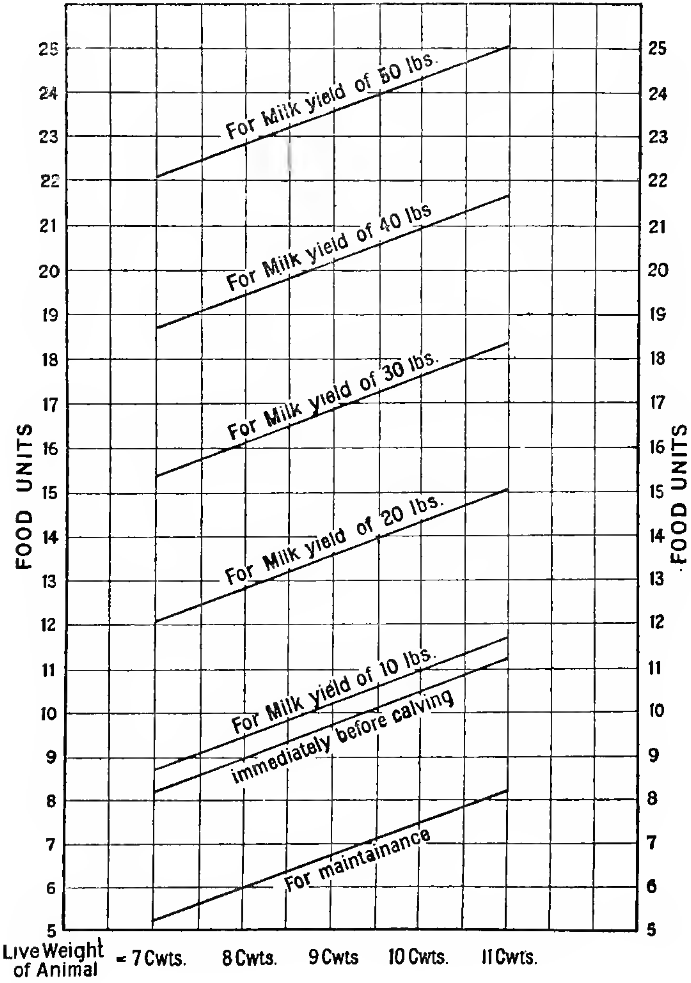
Nor is an early attempt made to have the artificially reared calf catch up the naturally fed. Indeed the attempt is rather delayed. Even if he change hands at weaning, say, at six or seven months old, the artificially reared calf is still owned by a farmer who derives his income largely from milk and is not willing to give extra food and attention to animals which do not produce milk. Thus the lean and undergrown calf grows into a lean and undergrown yearling. He may grow and fatten a little upon the summer pastures, but he is still too small, and he must go half-fed or starving another winter and recover and grow again on another summer's pasture before the fattening farmer will put him into his stalls. The fattening farmer's reason for wishing to have good-sized bullocks is simple. The fattened bullock is sold at, say, 40/- a hundredweight ; that is at 4.3 pence a pound, live weight. During the fattening period, he costs about tenpence or elevenpence and gains about two pounds in the day. Obviously, if a pound of carcase is put on at fivepence or fivepence halfpenny and sold at 4.3 pence, the bullock must make a loss. The fattening farmer's chief object is to convert the unsaleable part of his crops into manure, but, if he can avoid it, he prefers not to do so at a loss. If the bullock's fattening period lasts four months and the daily loss is twopence a day (say 10.6d.—8.6d.) then the farmer's total loss per bullock is twenty shillings. But the bullock which the farmer sells at forty shillings a hundredweight is stalled at about thirty-five shillings, and, so, five shillings are gained upon every initial hundredweight. Thus, the bullock which is to be fattened is not wanted till he weighs eight or ten hundredweights, and those who " store " him till he has attained this weight must allocate the loss—or, at any rate, the poor return—among them. That " storing " bullocks or any other stock involves a loss is not generally known; but loss or a poor return is inevitable to somebody, for the bullock, like the low-yielding cow, must always have a maintenance ration, and, when he is making no advance, still more, when he is going backward, as he sometimes does in winter, this maintenance ration is given away for no return whatever. Not only so, but, when the cost of the maintenance part of the ration is high in proportion to the cost of the whole ration and the bullock is making only a small advance, he, like the unprofitable cow, is either giving only a poor return or making a loss. When merchandise which has not been sold is stored till another season, the owner has to pay storage and interest on capital and run risk of his goods deteriorating, but the owners of live stock which are " stored " have also to pay for the rations which keep their stock alive.

In order to understand more clearly how losses are brought about by the use of inappropriate rations, we shall discuss some part of the more recent work of Fjord's successors in Denmark and Sweden. It was known, from investigations carried out by Kühn and Kellner, that a bullock weighing about nine cwts. could be maintained on seventeen or eighteen pounds of meadow hay, and that, for every hundredweight up or down, the hay ration had to be increased or decreased by about a couple of pounds. The Danes and Swedes confirmed these figures when applied to cows, with, however, an important alteration. They had extraordinary facilities for doing so. During the last twenty or thirty years, there have been many farmers' associations in Denmark and Sweden, in which the members combined together not only to buy feeding stuffs and sell butter and bacon, but also to collect information which might be useful to one and all in the industry by which they made their living. Not only did the members of these associations weigh their cows' milk daily or weekly and have it tested for fat at short intervals, but many of them weighed the food consumed and even the cows themselves. The data thus collected were then sent to central bureaus and there examined by competent investigators. It was expected, of course, since they were nurturing calves, that cows coming to the calving would need more food for mere maintenance than a bullock or a barren cow, but, from the data sent in to them, the investigators were able to name the exact quantity. If it be remembered that 2½ pounds of meadow hay have the same feeding value as 1 pound of barley, which is taken as the unit, a nine hundredweight bullock needs nearly seven food units. It was found that cows of the same weight coming to the calving needed about three units more. Cows weighing about nine hundredweights need about ten units, and, for every hundredweight up or down, .75 of a unit (2 pounds of hay divided by 2.5 ≐ .8) has to be added or subtracted. Still farther, it was found that, for the first ten pounds of milk she produced, the cow needed nearly another half unit, while for every additional pound produced, she needed another third of a unit. These results are expressed in the following table and in the diagram on page 72, which applies to cows weighing from seven to eleven hundredweights and yielding up to five gallons of milk a day. It can be applied to cows still heavier or lighter and giving still higher yields, by producing the cross lines in either direction and reading the perpendicular figures still higher.

	Food Units required by cows weighing				
	7 cwts.	8 cwts	9 cwts.	10 cwts.	11 cwts.
When in calf	8.2	8.95	9.7	10.45	11.2
Yielding 10 lbs. of milk	8.7	9.45	10.2	10.95	11.7
,, 20 ,, ,,	12.03	12.78	13.53	14.28	15.03
,, 30 ,, ,,	15.37	16.12	16.87	17.62	18.37
,, 40 ,, ,,	18.7	19.45	20.2	20.95	21.7
,, 50 ,, ,,	22.03	22.78	23.53	24.28	25.03

All animals have the power of accommodating themselves for a time to the quantity of food given them, and none more clearly than the cow. If she gets more than is necessary for current work, the surplus goes towards the accumulation of fat; if less, the fat store is called upon to make up for the deficit. In the latter half of the lactation period, when the milk yield is running down and less work being done, a cow which is reasonably well fed grows fat again and continues to do so till shortly before calving, when the calf's increasing demands may have the effect of slowing down the fattening.

After calving, the process is reversed, in good cows especially, for these, for a time, usually give more milk than the food can produce. In five gallons of ordinary milk there are about six and a half pounds of solids. If it were possible to feed the cow upon concentrates alone and she were able to convert a fifth of the ration—which is probably an over-estimate—she



would have to consume about thirty-eight pounds in the day. This she could do, perhaps, at a push, but her digestive apparatus is such that she must have so much bulky food that the proportion of the whole which is converted into milk solids is lowered to about a seventh or an eighth. Thus, if she is to produce five gallons of milk entirely from her food, and the ration is to contain a healthy proportion of bulky food, she must consume from forty-five to fifty pounds of solids ; and this she can not do for long. So, for a time, at any rate, she falls back upon the fat which is stored up in her body, and it is for the cow feeder so to adjust the proportions of long fodder, on the one hand, and roots and concentrates, on the other, that the cow shall get all or nearly all she wants from a ration which is within the stomach's capacity. Clearly, with good cows the proportion of concentrates must be high in the earlier part of the lactation, but may be gradually decreased as the yield decreases, while bad cows may be so bad that they may get enough for all the milk they produce from long fodder alone.

Point may be given to these remarks and the use of the feeding table illustrated at the same time by considering how the rations for a nine hundredweight cow might be made up. While her yield is at about five gallons, she requires 23.54—say 24—food units. Obviously, since 96 pounds (24 × 4) would be required, oat straw alone will not suffice, for the cow's capacity is limited to 35 or 40 pounds a day, from which only ten food units can be extracted, at the utmost. Upon this, with the help of her stored up fat, the cow might rise to a gallon or a gallon and a half for a few weeks and, then, run dry.

Nor can hay alone be used for a good cow, for even if forty pounds were consumed, not more than sixteen food units could be extracted from the ration, and, upon this, with the help of her stored up fat, the cow might rise to three gallons for a day or two, remain at two and a half for a few weeks, and then gradually decline.

If the hay were reduced to twenty pounds and eighty pounds of mangels substituted for the other twenty, the ration would then contain sixteen food units ($20 \div 2\frac{1}{2} = 8$ and $80 \div 10 = 8$) which might be enough for a cow yielding about

2½ gallons at the maximum, but not nearly enough for one capable of yielding five gallons.

In these last cases, the ration could be increased two or three food units by the addition of twenty or thirty pounds of mangels, but this, though roots are very highly digestible, approaches the dairy farmer's limit of roots and, as we shall see later, may lower the efficiency of the whole ration. Even so, though it now contains eighteen or nineteen food units, the ration is not enough for a good cow, and must be made up till it corresponds to her full capacity by the addition of cakes and meals. And, in all cases, it must be remembered that every pound of concentrates added to the ration reduces the need for hay by 2½ pounds and straw by 4, and, so, helps to keep the total bulk of the ration within the capacity of the stomach.

On the understanding that hay or straw and roots may be varied as they are at the farmer's command, and concentrates as their price and efficiency determine, we may now set down a few sample rations for cows of nine hundredweights at different stages during the lactation period:

When the yield is about 50 lbs. or 5 gallons a day:

Oat straw	8 lbs.	=	2	units	$({}^{8}/_{4})$
Hay	10 ,,	=	4	,,	$({}^{10}/_{2\cdot5})$
Mangels	84 ,,	=	8.4	,,	$({}^{84}/_{10})$
Bran	4 ,,	=	3.3	,,	$({}^{4}/_{1\cdot2})$
Bean meal	4 ,,	=	4	,,	$({}^{4}/_{1})$
Decorticated Cotton Cake	2 ,,	=	2.4	,,	$({}^{2}/_{\cdot85})$
			24.1 units.		

When the yield is about 4 gallons:

Oat straw	8 lbs.	=	2	units	$({}^{8}/_{4})$
Hay	10 ,,	=	4	,,	$({}^{10}/_{2\cdot5})$
Mangels	84 ,,	=	8.4	,,	$({}^{84}/_{10})$
Bran	3 ,,	=	2.5	,,	$({}^{3}/_{1\cdot2})$
Bean meal	3½ ,,	=	3.5	,,	$({}^{3\cdot5}/_{1})$
			20.4 units.		

When the yield is about 3 gallons :

Oat straw	12 lbs.	=	3 units	$(^{12}/_{4})$
Hay	8 ,,	=	3.2 ,,	$(^{8}/_{2\cdot5})$
Mangels	84 ,,	=	8.4 ,,	$(^{84}/_{10})$
Bran	3 ,,	=	2.5 ,,	$(^{3}/_{1\cdot2})$
			17.1 units.	

When the yield is about 2 gallons :

Oat straw	16 lbs.	=	4 units	$(^{16}/_{4})$
Hay	5 ,,	=	2 ,,	$(^{5}/_{2\cdot5})$
Mangels	80 ,,	=	8 ,,	$(^{80}/_{10})$
			14 units.	

When the yield is about 1 gallon :

Oat straw	20 lbs.	=	5 units	$(^{20}/_{4})$
Mangels	55 ,,	=	5.5 ,,	$(^{55}/_{10})$
			10.5 units.	

But certain cows need rations which are slightly different from those set down in the table because of the quality of their milk. The table is devized for cows giving milk containing 3.5 per cent. of butter fat, but cows giving milk of higher quality need more food, while those giving lower quality milk need less. According to investigations made in Sweden, the percentages of fat and the total solids (fat, sugar, albumen, and salts) in milk vary together as follows :

Fat	2 %	3 %	3.5%	4%	5 %	6 %
Total solids	10.2%	11.6%	12.3%	13%	14.4%	15.8%

It is therefore to be expected, since she converts more milk solids as the quality of her milk increases, that the cow must have more food. From data collected among Swedish farmers, Professor Nils Hansson found that, while the cow giving milk containing 3.5 per cent of fat produces 3 pounds of milk from one unit of food, cows giving milk containing

3.6, 3.7, 3.8, 3.9, per cent of fat produce only 2.95, 2.90, 2.85, 2.80 . . . pounds of milk from one unit. From these figures, it can be calculated that the "productive" part of the ration must be increased by $\frac{1}{11}$th, $\frac{1}{8}$th, (actually $\frac{1}{8.3}$) and $\frac{1}{3}$rd for cows giving 4%, 4.5% and 5% milk, while for cows giving only 3% milk the "productive" part of the ration may be decreased by $\frac{1}{13}$th. For instance, the ration for a nine hundredweight cow giving 5 gallons of milk containing 3.5 per cent of butter fat contains 23.53 food units, 7 of which are for maintenance and 16.53 for production. The addition for a similar cow giving 5 gallons of 5 per cent milk is $\frac{16.53}{3}$, namely 5.51 units, which now makes the total 29.04 (23.53 + 5.51). Obviously, with such a large increase in food units, the bulk of long fodder for this cow must be reduced as compared with that for the cow giving 5 gallons of only 3.5% milk. The following may be suggested as a suitable ration :

Hay	17½ lbs.	7 units	($^{17.5}/_{2.5}$)
Mangels	84 ,,	8.4 ,,	($^{84}/_{10}$)
Bran	4 ,,	3.3 ,,	($^{4}/_{1.2}$)
Decorticated cotton cake	4 ,,	4.7 ,,	($^{4}/_{.85}$)
Earthnut cake	4 ,,	5 ,,	($^{5}/_{.8}$)
Bean meal	1 ,,	1 ,,	($^{1}/_{1}$)
		29.4 units.	

It may have been noticed that, in this discussion, nothing has been said about albumen. Almost nothing need be said, for, unless an animal be fed with straw alone, albumen starvation is not likely. Growing stock need more albumen than older stock, but the very young have albumen in the milk, while those that are a little older have it in hay and roots. Good cows and hard-working horses cannot be fed to their productive capacity on long fodder alone, and the danger of albumen starvation is averted by concentrates, which must be given them.

The chief thing to be recommended in these rules is not that they suggest any violent change in the successful stock-feeder's practice, excepting with the dairy cow, but afford him the means of substituting one food for another which he may grow or buy more cheaply and find equally or even more effective. In the case of the dairy cow, a violent change is necessary, for, in addition to struggling with cows which are inefficient and wasteful, the dairy farmer frequently makes the double mistake of feeding the bad cows too well and the good ones below their full capacity.

Though British farmers are reputed to be the best cattle fatteners in the world, it is possible this reputation rests upon the success of a minority of their number. That all are not equally efficient is evident from the extraordinary variety in the rations fed and the unequal rates at which cattle are fattened. It has to be said, of course, that beef is sometimes a kind of bye-product, not necessarily negligible, but second in importance to another. On many farms, the bullock's first duty is to convert roots and straw into manure, his second to have himself fit for the butcher when the first has been accomplished : that is to have both duties coming to an end at the same time, and, when the first duty has been well performed and large crops of grain and potatoes thereby assured, the farmer does not always look too closely into the financial aspect of the performance of the second. " Stores " for winter fattening are usually bought in autumn, and, from then onwards, so treated that the last of them shall go to the butcher when the last of the roots and straw has been converted into manure. The question whether fattening might be made more profitable by the bullocks increasing more quickly in weight or the fattening period being shortened does not clearly arise ; consequently, no definite attempt has yet been made to determine either the maximum daily increase a bullock may possibly make or the nature of the most efficient ration. Since linseed cake came into use, early in the nineteenth century, many experiments have been made in fattening cattle, but these do not indicate, even approximately, the ration which is most efficient. Farmers are advised to give their stock " well-balanced " rations, but few who give this advice could say, with authority, the proportions of long fodder, roots, and concentrates which such a ration should contain.

A very exhaustive digest of the fattening experiments carried out in Britain from 1833 to 1908 was published by

Mr. Herbert Ingle in the 1909 volume of the "Transactions of the Highland and Agricultural Society of Scotland." By applying the Scandinavian system of food units to these experiments, it is possible to distinguish the efficient from the inefficient rations and indicate the chief causes of inefficiency. Among other data, Mr. Ingle's digest contains these which are pertinent to our present purpose:

1. The duration of each experiment.
2. The average live weight per head of each set of animals during the experimental period.
3. The average daily ration.
4. The average daily gain in weight per head during the experimental period.

The only use now made of the first of these four kinds of data is to eliminate from consideration all experiments which lasted less than 70 or more than 170 days: that is all experiments which lasted sensibly shorter or longer than the normal period of fattening, which averages about four months. A few experiments are left out of consideration because the rations or the daily gains are obviously inaccurately reported, and a larger number because the descriptions of some rations are not free from ambiguity.[1]

Then the remaining experiments are arranged in groups according to the weights of the experimental animals, and the food units in each ration calculated and plotted against the daily gains each produced, as in the diagram on page 79.

From this diagram it is obvious that the food units consumed by fattening cattle rise with the weights of the cattle. The rise is indicated by the dotted line drawn across the diagram to join up the cross marked in each group with the corresponding crosses in the groups on either side. The positions of the crosses are found by plotting the average food units consumed against the average daily gains made by each group of cattle. It is obvious, since it makes only one serious deviation, at the ten cwt. group, that, had there been more experiments, this dotted line would have been

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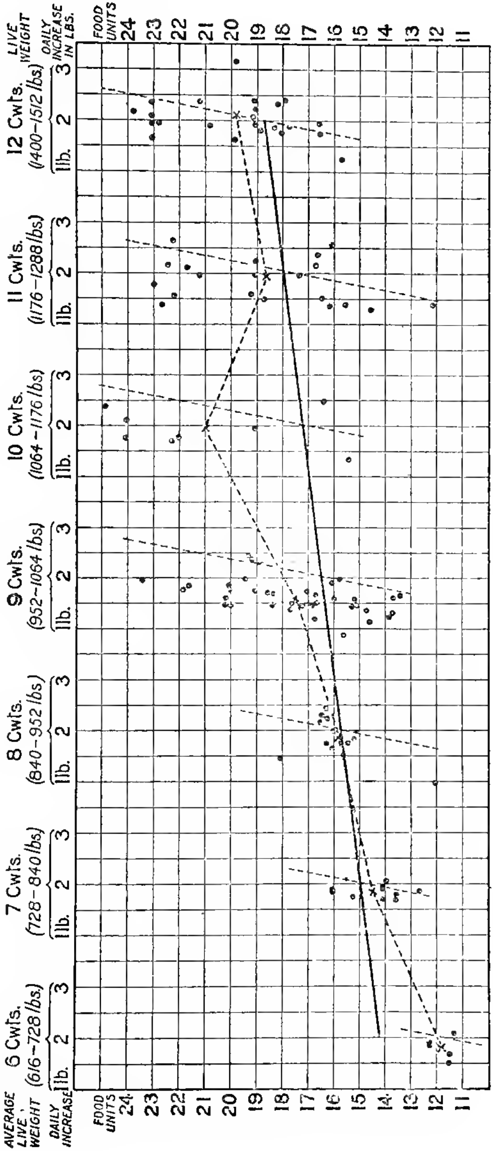
[1] In Mr. Inglis's digest the age and sex of the animals are given in most cases, but, as may be seen from the diagram, the food consumed is not determined by age or sex but by weight.


AVERAGE LIVE WEIGHT
DAILY INCREASE
FOOD UNITS
LIVE WEIGHT
DAILY INCREASE IN LBS.
6 Cwts. (616–728 lbs.)
7 Cwts. (728–840 lbs)
8 Cwts. (840–952 lbs)
9 Cwts. (952–1064 lbs)
10 Cwts. (1064–1176 lbs)
11 Cwts. (1176–1288 lbs)
12 Cwts. (1400–1512 lbs)
1lb.
2
3
24
23
22
21
20
19
18
17
16
15
14
13
12
11

approximately straight. Not only so, but, on the assumption that a certain number of food units should make a pound of beef in all weights of cattle, just as a certain number of food units makes a gallon of milk in all weights of cows, the line should not only be straight but also parallel to the lines for maintenance and milk yields. We are, therefore, entitled to straighten out this line and say that cattle fed with the average number of foods units appropriate to their live weights should make the average daily gains, both as indicated in the straightened line.

But we can aim higher than the average. Many of the experimental animals made more than the average daily gains upon less than the average food units. The chief reason for this, as we shall see presently, was that their rations were better "balanced." It will be noticed, by the diagram, that one of the 12 cwt. groups of cattle made a daily gain of 3.3 pounds upon a ration which contained 19.8 food units. But this gain is an exceptional accomplishment which, as yet, may be aimed at only in exceptional cases. Still higher gains have been made, over short periods, upon good young pasture, but, till we know better how to simulate, in a winter ration, the succulence, digestibility, and nutritive appropriateness of such a pasture, we shall do well to aim at a lower gain.

It will be noticed, by the diagram, that, in nearly every group, a fair proportion of the lots make a daily gain of two pounds or over, and, since this is capable of frequent accomplishment, we shall, in the meantime, make our aim a gain of two pounds a day. It will also be seen that two sets of animals in the 12 cwt. group make over two pounds a day upon 18 units, five in the 11 cwt. group make similar increases upon 16 to 18 units, one in the 10 cwt. group makes 2.45 pounds upon 16.4 units, one in the 9 cwt. group makes very nearly two pounds upon 15.8 units, and two in the 6 cwt. group make almost two pounds a day upon just over 14 units. A line drawn through the average of these figures would indicate the number of food units necessary to produce a daily gain of two pounds; but, as the rations which these figures represent may have been exceptional, just as the gain of 3.3 pounds was exceptional, we shall draw a less ambitious line which shall represent the units necessary, with rations which are not exceptional. This line has been drawn across the diagram and indicates that, in order to gain two pounds a day with non-exceptional stock and rations :

6 cwt. animals require 14.25 food units a day
7 ,, ,, ,, 15 ,, ,, ,,
8 ,, ,, ,, 15.75 ,, ,, ,,
9 ,, ,, ,, 16.5 ,, ,, ,,
10 ,, ,, ,, 17.25 ,, ,, ,,
11 ,, ,, ,, 18 ,, ,, ,,
12 ,, ,, ,, 18.75 ,, ,, ,,

The line may be produced in either direction for heavier or lighter animals.

But the diagram indicates that the rations varied greatly in efficiency. For instance, in the twelve cwt. group, daily gains of about two pounds were produced by rations containing only about eighteen food units in some cases and as many as twenty-three or twenty-four in others, while, in the same group, rations containing about nineteen units produced daily gains varying from about 1.8 to 2.4 pounds. Can any comparison be made of the relative efficiencies of the rations ?

Just as a line drawn horizontally through the whole of the plottings shows how the food units consumed rise with the weights of the animals, so another line drawn vertically through the average of the plottings in each group will show how the daily gains rise with the food units consumed. Such lines have been drawn through every group, the first through the six cwt. group, because it contains the greatest number of plottings, and the others through the other groups, all parallel to the first. As, however, we have aimed, meanwhile, at producing a daily gain of two pounds, the vertical lines have been drawn through the horizontal line at the points where daily gains of two pounds are plotted. Those rations which fall to the left of the vertical line are less efficient, those to the right more efficient, than those on the horizontal line which produced a daily gain of 2 lbs. ; and their efficiencies can be roughly measured by counting their distances to left or right of the vertical line. For instance, the efficiencies of the five rations in the 12 cwt.

No.	Live Weight	Food-units consumed	Daily gain	Ration				Relative Efficiency
				Straw	Hay	Roots	Concentrates	
			lbs.	lbs.	lbs.	lbs.	lbs.	
1	6 cwts.	11.59	1.51	0	8.5	26.5	4.5	— 5
2		11.59	1.67	0	8.5	26.5	4.5	— 3
3		12.34	1.85	0	8	46	4.03	— 2
4		12.34	1.90	0	8	46	4.03T	— 1
5		11.37	2.07	0	8.5	26.5	4.5	+ 2
6	7 cwts.	15.34	1.73	0	7.7	56	5.56T	— 3
7		14.14	1.69	0	10.4	28	6.06T	— 2
8		16.14	1.87	0	12.5	42	7	— 2
9		16.07	1.81	0	12.5	42	7	— 2
10		16.15	1.87	0	12.5	42	6	— 2
11		13.67	1.68	0	7.7	65	3.4	— 2
12		13.67	1.76	0	7.7	65	3.4	— 1
13		14.18	1.96	5.77	7	50	4.37	0
14		14.18	1.96	5.77	7	50	4.36	0
15		12.78	1.85	0	14.63	0	6 T	+ 1
16		14.06	2.05	0	11.58	28	5.52T	+ 2
17	8 cwts.	18.11	1.44	8	0	110	4	— 8
18		12.1	.96	0	0	109	0	— 6
19		16	1.42	13.6	0	0	10.4	— 6
20		16.35	1.71	0	12.5	42	6	— 3
21		16.04	1.63	0	14	56	4.5	— 3
22		15.53	1.73	0	13.8	56	4.58	— 2
23		15.24	1.82	0	13.8	56	3.82	— 1
24		16.58	2.14	10	5	50	6	+ 1
25		16.53	2.26	10	5	50	6	+ 2
26		16.3	2.21	1.57	7.44	73	5.36	+ 2
27		16.34	2.42	1.57	7.44	73	5.36	+ 4
28	9 cwts.	15.68	.88	7	0	126	0	— 10
29		20.19	1.49	7	0	130	4	— 10
30		20.08	1.43	3	7	100	5.3	— 9
31		16.80	1.16	0	7	126	0	— 9
32		21.96	1.72	4	4	105	8.84	— 8
33		20.27	1.57	7	0	130	3.67	— 8
34		23.48	1.93	4	4	105	8.85	— 7
35		14.65	1.11	8.5	0	50	7.25	— 7
36		21.72	1.81	4	4	105	8.86	— 7
37		18.41	1.43	7	0	150	0	— 7
38		17.75	1.38	3.75	8.25	95.5	3.49	— 6

FOOTNOTE:—The rations marked T received in addition small quantities of treacle molasses.

group containing about 19 food units may be represented in order from left to right by the figures— 3, — 2, — 1, + 2, and + 3. The efficiencies of all the rations in the diagram,

No.	Live Weight	Food-units consumed	Daily gain	Ration				Relative Efficiency
				Straw	Hay	Roots	Concentrates	
			lbs.	lbs.	lbs.	lbs.	lbs.	
39	9 cwts.	20.08	1.78	3	7	100	5.3	— 6
40		17.75	1.49	3.75	8.25	95.5	3.49	— 6
41		17.22	1.48	5	0	114	3.02	— 6
42		16.77	1.47	8.16	0	112	3	— 6
43		16.92	1.43	10	0	75	5.3	— 6
44		20.08	1.81	3	7	100	5.3	— 5
45		19.03	1.71	10	0	100	0	— 5
46		18.41	1.64	5	0	120	3.88	— 5
47		18.58	1.67	5	0	108	3.88	— 5
48		13.90	1.20	9.97	0	50	6.67	— 5
49		15.28	1.42	9.08	0	50	10	— 5
50		14.77	1.33	8.36	0	50	9.37	— 5
51		16.77	1.61	8.16	0	112	3	— 4
52		13.81	1.26	7.9	0	50	8.5	— 4
53		16.00	1.54	10	0	80	4	— 4
54		15.16	1.43	8	0	84	3.88	— 4
55		15.25	1.51	7	0	95	4	— 3
56		19.54	1.98	3.54	3.54	56	9.74	— 3
57		17.11	1.70	10	0	100	4	— 3
58		16.00	1.89	8	0	109	3	— 1
59		13.75	1.58	7	0	120	0	— 1
60		13.48	1.60	5	0	84	3.88	— 1
61		15.83	1.94	0	16	28	6.5	0
62		19.24	2.38	3.07	3.08	90	6.1	+ 1
63		19.30	2.42	3.78	3.78	56	9.74	+ 2
64	10 cwts.	24.09	17.3	4	4	112	8.7	— 9
65		22.33	1.69	4	4	112	8.7	— 8
66		22.02	1.78	15	0	90	6	— 7
67		24.06	2.10	4	4	112	8.7	— 6
68		15.49	1.31	0	22	0	6	— 5
69		24.97	2.38	7	0	155	3	— 4
70		19.05	1.97	0	0	131.11	4.6	— 2
71		16.41	2.48	8	0	108.75	3	+ 5
72	11 cwts.	22.76	1.33	4	4	112	8.6	— 11
73		22.23	1.52	4	4	112	8.6	— 9
74		23.04	1.71	4	4	112	8.6	— 7
75		18.78	1.50	9.5	5	0	13 T	— 6
76		19.22	1.59	15	0	90	6.1	— 5

with particulars as to the food units and amounts of long fodder roots and concentrates contained in each and the daily gains produced, are set out in the tables herewith.

No.	Live Weight	Food-units consumed	Daily gain	Ration				Relative Efficiency
				Straw	Hay	Roots	Concentrates	
			lbs.	lbs.	lbs.	lbs.	lbs.	
77	11 cwts.	16.19	1.35	9.6	0	45	8	— 5
78		16.51	1.50	2.71	7.08	29	10.23	— 4
79		15.61	1.37	7	7	0	9 T	— 4
80		14.60	1.28	14.1	0	0	10	— 4
81		22.51	2.11	0	0	127.03	7.72	— 3
82		21.21	1.98	15	0	90	8.59	— 3
83		21.72	2.06	14	7	63	8	— 3
84		19.11	1.97	0	8.88	40.34	10.18	— 1
85		12.18	1.35	0	17	48.4	0	— 1
86		17.42	1.98	2.92	6 55	32.4	9.64	0
87		19.07	2.22	0	8.88	40	10.18	+ 1
88		22.24	2.60	14	7	63	8	+ 2
89		16.72	2.15	4	6.97	39.9	9	+ 3
90		16.68	2.35	4.1	6.9	39.5	9	+ 5
91		16.06	2.54	0	15.49	44.3	4.32	+ 7
92	12 cwts.	23.11	1.64	9.5	5	82	12.5 T	— 8
93		19.90	1.60	11	5.5	56	9.4 T	— 6
94		23.06	1.92	7	7	70	10.5	— 5
95		23.81	2.11	5	5	115	8.8	— 4
96		22.92	1.95	5	5	107	8.8	— 4
97		15.74	1.26	11	5.5	0	9.4 T	— 4
98		23.11	2.07	9.5	5	82	12.5 T	— 4
99		20.83	1.91	5.5	5.5	84	8.8	— 3
100		18.98	1.78	11	5.5	56	9.4 T	— 3
101		18.03	1.73	8	8	42	8.8	— 2
102		23.11	2.31	9.5	5	82	13.5	— 1
103		19.07	1.90	0	10	95	5.35	— 1
104		18.37	1.82	4	12	34.6	8.1	— 1
105		17.78	1.86	0	16.1	39.2	9.07	0
106		16.61	1.76	7	7	0	10.5 T	0
107		19.15	2.04	3.5	10.6	56.6	8.1	0
108		21.23	2.39	0	16.2	40.5	9.3	+ 1
109		19.02	2.20	0	14	45	8.19	+ 2
110		16.61	1.94	3.55	7.66	32.42	9.11	+ 2
111		19.07	2.38	0	10	95	5.35	+ 4
112		18.19	2.30	0	11	45	8	+ 4
113		17.95	2.38	3.82	7.03	32.2	9.76	+ 5
114		19.85	3.13	0	13.73	40.2	8.66	+ 10

In all these experiments, no lot of cattle was fed upon either long fodder alone or concentrates alone. One lot, No. 18, was fed upon roots alone (109 lbs.), but the gain made showed the ration to have an efficiency of — 6. Six lots were fed upon long fodder and roots only, but always with minus efficiencies, namely :

No.	Straw	Hay	Roots	Efficiency
	lbs.	lbs.	lbs.	
28	7	0	126	— 10
31	0	7	126	— 9
37	7	0	150	— 7
45	10	0	100	— 5
59	7	0	120	— 1
85	0	17	48.4	— 1

Eight lots were fed upon long fodder and concentrates only, with minus efficiencies in six cases, namely :

No.	Straw	Hay	Concentrates	Efficiency
	lbs.	lbs.	lbs.	
15	0	14.63	6	+ 1
19	13.6	0	10.4	— 6
68	0	22	6	— 5
75	9.5	5	13	— 6
79	7	7	9	— 4
80	14.1	0	10	— 4
97	11	5.5	9.4	— 4
106	0	7.7	10.5	0

Two lots were fed upon roots and concentrates only, with minus efficiencies in both cases, namely :

No.	Roots	Concentrates	Efficiency
	lbs.	lbs.	
70	131.11	4.6	— 2
81	127.03	7.72	— 3

These results confirm the opinions formed by farmers, since the introduction of roots and concentrates made winter fattening possible, that the best results are got when all three constituents, long fodder, roots, and concentrates, are combined in a ration. They also suggest, as a consideration of the nature of a good young pasture and the results it produces would suggest, that the efficiency of a ration is reduced when it is made too succulent, by too many roots, or too indigestible and innutritive, by too much straw.

On scanning the tables, it will be seen that the efficiencies of the rations which contain all three ingredients do not vary directly with the concentrates, for, in the rations falling to the right of the vertical lines, these vary between three pounds and ten. Nor, when roots and concentrates are in fair proportions, are the efficiencies of the rations seriously affected by large quantities—say 12 to 14 pounds for smaller animals and 14 to 18 for larger—of hay or even of hay and straw in about equal proportions, though they seem to be affected when straw given alone rises beyond about two-thirds of these quantities. The chief depressing factor is the roots which, though very helpful in moderate quantities, are harmful in large. As yet the limit where helpfulness ends and harmfulness begins is not known—no experimenter has tried to find it—but a glance down the tables, in which it is made obvious that inefficiency is generally high when the quantity of roots is high, suggests that the limit is somewhere between 70 and 90 pounds for the heavier animals and 60 and 80 for the smaller. Meantime, therefore, and till we know better, we might suggest the following as an appropriate winter ration for a 9 cwt. bullock which is expected to increase in weight by not less than two pounds a day :

Hay 4 units = 10 lbs.
Oat straw 1 ,, = 4 ,,
Mangels 8 ,, = 80 ,,
Concentrates 4 ,, = 4 ,, more or less, according to the nature of their ingredients.

CHAPTER VII

BREEDING

HAVING considered the chief rules which lie at the root of success in stockbreeding, it now remains to see how these are to be applied in a few particular cases. Before doing so, however, it will be well to glance at the rôles played by different parts of the country in agricultural production. Just as Yorkshire specializes in wool, Lancashire in cotton, and Ulster in linen, so different parts of the country specialize in different agricultural products and are dependent upon each other for raw and partly finished materials. The chief causes of this specialization are soil, climate, markets and communications, the bent of the farmers, and the capacity of farmers and workmen.

As a rule, the usual crops yield profits, *as crops*, in the following order: potatoes, roots, grain, hay, and pasture. Consequently, where soil, climate, men, and the other conditions are suitable, the farmer grows the more profitable to the exclusion of the less profitable crops. Thus, a large part of the eastern half of Britain, from Forfarshire to the Thames, and other equally favoured districts running through to the western side of the country, are given over chiefly to grain, roots, and potatoes. In these parts, pasture is at a minimum and stock raising not the rule. Consequently, the farmers must depend upon other parts to supply them with stock to convert their unmarketable roots and straw into marketable beef and mutton and crop-raising manure. These farmers draw their store sheep from the highest parts and their store cattle from the western half of Britain and from Ireland, where much of the land, for climatic and other reasons, is believed to be better under pasture than grain and roots.

The bulk of the calves which eventually come to the fattening farmer are born upon one or other of three kinds of dairy farms: the whole milk farm, the cheese farm, or the butter farm. As a rule, whole milk farmers sell nearly all their calves shortly after they are born, while cheese-making farmers keep only the heifer calves from their best milking cows. The calves from both these sources are reared either by butter-making farmers, with whom calves are a bye-product, or by others who aim to have their calves so reared that they shall come to the butcher while still young.

The majority of the calves which are eventually fattened in the grain and root growing parts of England and Scotland are reared by butter-producing farmers upon skim or separated milk and substitutes for the butter fat of which it has just been deprived. But, as the milk is usually less in quantity than nature intended it to be, and the substitutes low both in quantity and quality, calves reared in this way make slow progress and, at weaning time, are a hundredweight or more lighter than calves originally like them which have been suckled. In the first winter after weaning, their rations are hay, or hay and straw, sometimes a few roots, very often grazing by day, and a pound or two of cake or cake and grain. On this, they increase in weight from a pound to a pound and a half a day. In the following spring or autumn, they fall into the hands of the grazier, with whom they remain till the fattener wants them. In the grazier's hands, they generally move to better and better pasture, till, when over two years old, the pastures in which they then find themselves may be good enough, with the help of a pound or two of cake, to make them ready for the butcher. But, as the grazier provides but little hay or straw and seldom roots against winter, the rate of the summer progress is seldom maintained and, sometimes, even reversed, in winter. Thus, since the profits in raising stores can never be great, because of the high proportion which the maintenance part of the ration bears to the whole, it is possible they may be decreased or even turned into loss by progress being slowed down or reversed in winter. It would probably be more profitable for stock-keepers as a whole, if store cattle were sent to the fattener before their second winter, when they are approaching two years old, but, at this time, they are too old for the rearer and too small for the fattener, and must remain in the indifferent care of the grazier.

The calves which are sold by whole milk producers and cheese makers to farmers who do not make everything subservient to butter are treated more liberally, probably more profitably, by those who buy them and rear them. Those which are hand-reared are usually given a little more milk and meals, and, so, at weaning time, are better grown and in better condition. During their first winter, they are well housed and sheltered, more generously fed and better cared for, and go to pasture the following spring in condition to make rapid growth throughout the summer. In autumn, the best of them are put up to fatten at once, the next best are stored for a while but fattened off before spring, while the backward are kept on for further grazing. Calves which are suckled are usually put to better milking cows, along with the cows' own calves, and, thus, such cows suckle two calves at a time. With specially good cows which calve early in winter, the first two calves may be weaned when summer grazing begins and their place taken by one or even two others.

These suckled calves are nearly always well grown and usually in good condition. The majority are weaned in autumn. With the best fatteners, they are wintered upon hay, or hay and straw, and an average of three stones of roots and two or three pounds of cake and grain. Thus they are not only kept growing, but in good condition. In spring, they are put upon good, young pasture, and, when this begins to fail, as the summer proceeds, given two or three pounds of cake and grain in addition. Thus, they are ready for the butcher at almost any time. If prices are high, they can be sold off the pasture ; if prices are low or likely to rise, they may be house-fed till the rise takes place.

From this short account of how cattle which are eventually to be fattened are reared and fattened, it is obvious that the cattle themselves should be capable of quick and vigorous growth and rapid fattening. But it is equally obvious that for the successful attainment of these, two antecedent factors are a prime necessity, namely, plenty of appropriate foodstuffs and, for the rearing period, a plentiful milk supply. Appropriate foods may be raised on the farm or bought from the merchant, but milk is to be got from the cow alone. It was shown in Chapter VI that the whole milk seller keeps low yielding cows at a serious loss and that his profits are at their highest when his cows' yields are at their highest. This holds equally with cheese makers, butter producers, and calf rearers, for, in all three cases, poor-yielding cows require a larger proportion of the available food for mere maintenance, and have a smaller proportion left over to produce cheese or butter or calves. Thus, in these islands, at any rate, economic cattle raising is concurrent with high-yielding cows.

Nor are cattle the only kind of stock for which milk is important. In the mare-and-foal classes at important shows, the best foals are nearly always running beside dams which are good milkers, and, in good racing studs, the dams of the most promising foals usually give obvious signs of being able to give their progeny a favourable start. In the breeds of cattle specially set apart for beef production to which the pernicious system of foster-mothering has not yet been introduced, the wiser breeders give heed to the milk-giving capacities of their cows as revealed to them by the vigour and promise of their calves, and no flock of sheep can be maintained at a high standard unless the ewes which rear the vigorous lambs are retained and those which rear the backward ones rigorously culled.

Next in importance to milk come the other things for which live stock are reared and kept: beef in cattle, strength and speed in horses, mutton and wool in sheep, and bacon in pigs. Success in the selection of breeding stock to produce these other things depends first upon the accuracy of the selector's eye in identifying animals which carry them already or are capable of doing so when asked: animals, for instance, which are already fat or are capable of being easily fattened: and, next, upon the capacity of the selected stock to beget their "like" and breed true.

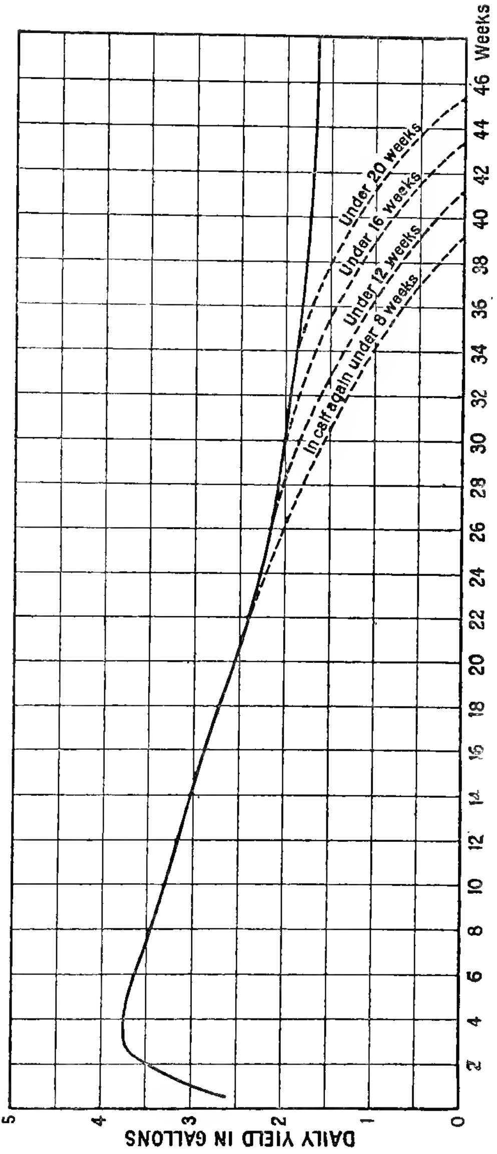
The failure of animals to breed true is the chief cause of stockbreeders' disappointments, and there is only one way to avoid it, namely, to test them through their produce. It will be remembered that all kinds of stock breed true as regards recessive characters. Chestnut breeds of horses always throw chestnut foals, red breeds of cattle red calves, horned cattle horned calves, and so on. Thus, with recessive characters, no test is necessary. It is in their dominant characters that stock may not breed true. A black bull, with cows of his own breed, may throw black calves only, but this does not prove him to be pure as regards his colour, for all the cows may have been pure and given him no chance to disclose himself. If, however, such a bull gets only black calves with red cows, doubts as to his purity vanish as the number of his calves increases ; but, if he gets one red calf with a cow of any colour, his impurity is clearly established. A round-rumped bull is not to be judged pure in that respect unless his calves from square-rumped cows are round, but is to be considered impure so soon as he throws a single square-rumped calf from any cow. A thick-fleshed bull is not to be judged pure by his progeny from similar cows but rather by his progeny from thin-fleshed cows. Expressed as a general statement, it might be said that animals are not to be judged by their progeny from stock as good as themselves, but rather by their progeny from inferior stock.

The identification of stock for their milk-producing capacity, however, is not to be accomplished by the eye alone, nor are the results of the breeding test to be known quickly. A good judge of beef cattle may form a sound opinion as to the breeding capacity of a beef bull when his first crop of calves is still young and the bull himself is little over two years old, but no clear opinion as to the capacity of sires or dams to leave milk-producing progeny can be formed till their daughters come into profit. The marks of a good milking cow are often held to be many and various, but all may be reduced to two, namely, a capacious udder and vigorous digestion. These are not readily identified, however, in a calf or even in a heifer. Besides, though a heifer's digestion may be inferred by the way she thrives upon a rough pasture or rough fodder, she may, after all, be suited for fattening only, not for milk production. Thus, we must wait till she comes in profit before we begin to form an opinion as to herself and her parents.

Apart from that due to inheritance, the variations to which milk yield is liable, must be considered more closely before any scheme of action can be laid down. The chief causes of these depend upon : (1) the " condition " of the cow at calving time and the cause of this " condition " ;

(2) food; (3) early or late pregnancy and, therefore, the lengths of time between calvings; (4) the time of the year in which the cow calves, and (5) the age of the cow. These have now been examined by several careful workers, and it is possible to give them fair and reasonable consideration.

If fed with sufficient food of average quality, a heifer is usually in good condition at her first calving. After calving, all cows fall off, heavy milkers especially, but recover again in a few months and, with sufficient and appropriate food, are in good condition again before the next calving. The falling off is undoubtedly due to the fat stored up in the cow's body being used in assisting to produce the higher milk yield in the early part of the lactation. If, through improper food, underfeeding, over-prolonged lactation, or any other cause, condition is not recovered before calving, the yield in the early part of the following lactation is reduced, for good cows especially. The normal maximum may be reached, but is maintained for a short time only. The yield is similarly affected if the cow be underfed after calving, and, for this reason, cows frequently fail to reach their full capacity. The milk yield fluctuates from day to day, but, apart from this, rises to its maximum a few weeks after calving. In the following diagram, which is constructed from data collected in Lord Rayleigh's herd, by Mr. W. Gavin, the continuous line shows how the yield rises and gradually declines for cows which are not in calf against the dotted lines for cows which are in calf at different intervals after their previous calving. Each square represents about seven gallons of milk. If the cow which is in calf again about twelve weeks after her previous calving be taken as the normal, the diagram shows that the yields of three-and-a-half-gallon cows are decreased by forty to fifty gallons on the whole lactation when in calf a month too soon and increased by a similar quantity when in calf a month too late, by double that quantity when two months too late, and so on. Since pregnancy does not affect the milk flow during its first twelve to sixteen weeks, the year's yield of a three-and-a-half-gallon cow which is not in calf again within about thirty weeks of her previous calving may be raised from about 700 to about


Weeks
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
0
1
2
3
4
5
DAILY YIELD IN GALLONS
Under 20 weeks
Under 16 weeks
Under 12 weeks
In calf again under 8 weeks

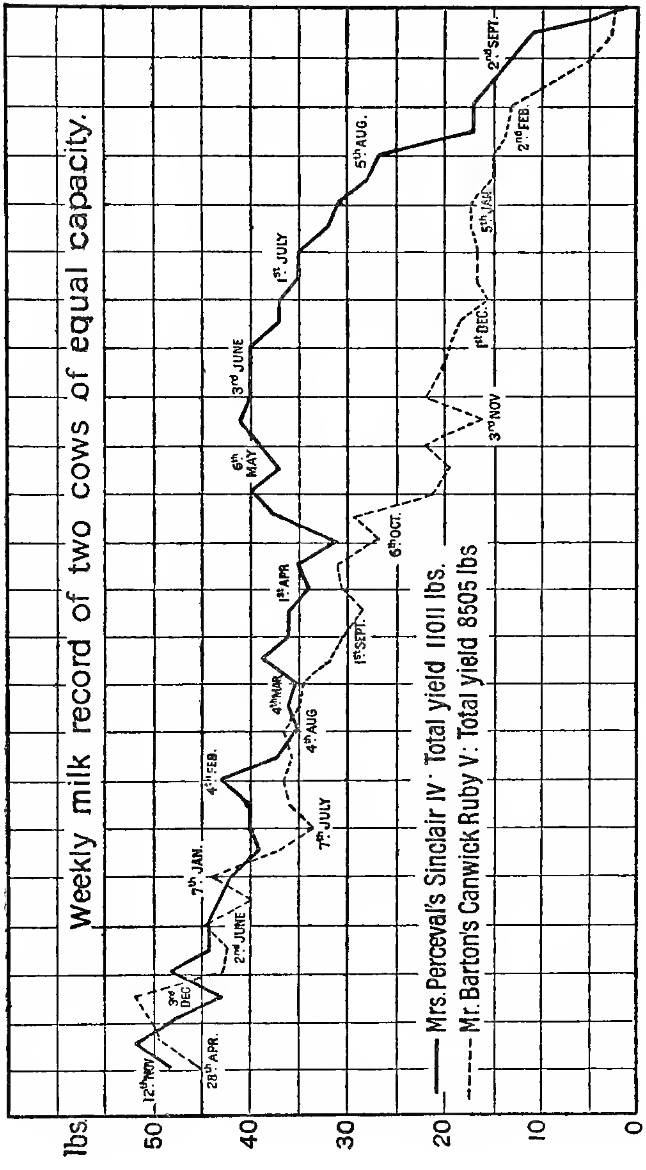
900 gallons : that is by more than twenty-five per cent above the normal. Thus, a normal yield of 1,000 gallons may be turned into a spurious one of 1,250 gallons by the next lactation being delayed.

As may be seen by the following table, a cow's true capacity may also be obscured by the time of the year in which she calves. The figures are taken from records made in the island of Fyen in Denmark, in Ireland, and Yorkshire. Allowance has to be made for the facts that the grazing season is shorter in Denmark than in Britain and that many of the Yorkshire cows received considerable quantities of concentrates while on pasture :

Month of calving	Denmark		Ireland		Yorkshire	
	Number of cows	Average annual yields in lbs. Danish	Number of cows	Average annual yields in lbs. English	Number of cows	Average annual yields in gallons
January	112	7803	83	7217	51	641
February	139	7523	109	7354	52	679
March	173	7423	121	7289	58	689
April	142	6910	118	6329	50	666
May	104	6622	71	5210	39	638
June	83	6342	25	6986	27	665
July	43	5800	21	7388	24	617
August	74	7400	45	6641	32	667
September	104	7950	44	8543	42	614
October	156	8549	74	7503	37	715
November	188	8299	51	8224	32	671
December	154	7822	49	7474	40	756

This great difference between the winter-calved and summer-calved cow seems to be brought about by the former being better fed again and, perhaps, stimulated to a fresh spurt by pasture, while the latter are worse fed in autumn and receive no similar stimulant. This is obvious from the diagram on page 95, which shows the records made by two Irish cows of equal capacity, one of which calved in November, the other in April.

Since it is liable to these variations, some of which are very large, it is obvious that the yield for a single or even for several lactation periods cannot be taken as a true measure of the cow's milking capacity, but is much more accurately


Weekly milk record of two cows of equal capacity.
lbs.
50
40
30
20
10
0
12th NOV.
28th APR.
3rd DEC.
2nd JUNE
7th JAN.
4th FEB.
7th JULY
4th AUG.
4th MAR.
1st SEPT.
1st APR.
6th OCT.
6th MAY
3rd NOV.
3rd JUNE
1st DEC.
1st JULY
5th JAN.
5th AUG.
2nd FEB.
2nd SEPT.
Mrs. Perceval's Sinclair IV. Total yield 11011 lbs.
Mr. Barton's Canwick Ruby V. Total yield 8505 lbs

represented by the daily yield when the milk is at the flush, a few weeks after calving. This, so long as the cow is in good health and fair condition, is subject to very little variation. It fluctuates, of course, from day to day, and, for this reason, the representative figure is not to be obtained from one abnormally high yield maintained only for a day or two, but from the average of ten to fifteen days' yields. This may be found by simple calculation, by plotting the yields and running a curved line through them, or, as Mr. Gavin suggested, by taking the highest yield maintained over three successive weekly records. For instance, if three such records are 59, 58, and 57 in one case, and 36, 37, and 36 in another, the representative figures are 57 and 36.

This figure may also be used to tell the total probable yield over a whole normal lactation. For a winter-calved cow, it is to be multiplied by 200, and for a summer-calved cow by 190 to 180: according as the cow calves in the worse or the better summer months. Mr. Gavin's figures are 195 for cows calving between September and May, and 187 for cows calving between June and August. A glance at the diagram on page 93 will show how closely the higher figures indicate the total yield for normal lactations. The rate at which the milk yield increases as the cow grows older has also been investigated, and it is now possible to express it diagrammatically with approximate accuracy. A cow's yield rises from lactation to lactation till she is eight years old, and then declines inversely as it rose. The following table shows the average daily yields of cows of the larger breeds exhibited at the London Dairy Show in 1911 and eight or ten previous years.

Age of cows	Daily yield	Number of cows
3 years	39.3 lbs.	14
4 ,,	47.0 ,,	7
5 ,,	51.6 ,,	35
6 ,,	55.4 ,,	60
7 ,,	56.9 ,,	50
8 ,,	58.0 ,,	30
9 ,,	54.2 ,,	12
10 ,,	56.9 ,,	7
11 ,, and over	60.1 ,,	5

These figures are few, however, especially for the younger and older ages: for the former because there had been a three-year-old class for a few years only, and, at the time, no four-year-old class; for the latter through depletion of their ranks. Most of the cows sent to such a show are near the period of maximum yield, so the figures may be taken as representing their milking capacity closely.

Mr. Gavin collected data from over 300 cows in Lord Rayleigh's herd, every one of which he was able to follow through their first five lactations, a considerable proportion through their sixth, a smaller through their seventh, and a still smaller through their eighth. He takes the highest yields maintained over three successive weighings, and his figures are as follows:[1]

Lactation	Yield	Number of cows
First	9.3 quarts	320
Second	12.8 ,,	313
Third	14.2 ,,	326
Fourth	14.9 ,,	328
Fifth	15.4 ,,	323
Sixth	15.85 ,,	221
Seventh	15.51 ,,	148
Eighth	15.48 ,,	83

Dr. Raymond Pearl, now of Johns Hopkins University, and Mr. J. R. Miner, of the Maine Agricultural Experiment Station, have collected a still larger body of data from the 1908 and 1909 Reports of the Ayrshire Cattle Milk Records Committee[2] which summarizes as follows:

Age of cow	Mean weekly yield	Number of cows
2 Years	13.61 gallons	86
3 ,,	13.84 ,,	1441
4 ,,	15.23 ,,	1118
5 ,,	16.46 ,,	909
6 ,,	17.47 ,,	804
7 ,,	18.05 ,,	712
8 ,,	18.26 ,,	637

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[1] Journal of Agricultural Science, vol. v., p. 377.

[2] Journal of Agricultural Research, vol. xvii., p. 285.

Age of cow	Mean weekly yield	Number of cows
9 years	18.56 gallons	459
10 ,,	18.74 ,,	320
11 ,,	18.11 ,,	202
12 ,,	18.46 ,,	116
13 ,,	18.75 ,,	62
14 ,,	17.95 ,,	40
15 ,,	18.13 ,,	21
16 ,,	17.80 ,,	8

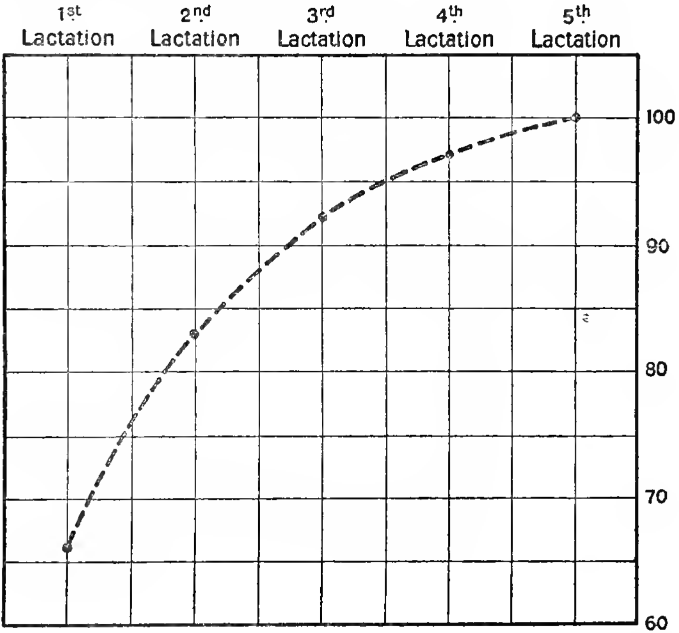
Of these data, Mr. Gavin's are the most useful, chiefly because they have been collected entirely from the same cows. The three sets have not been collected upon the same basis however, and must be criticized if they are to be used jointly. The first set is collected by age and maximum yield, the second by lactation and maximum yield, the third by age and average yield: that is, the lactation yield divided by the number of weeks in milk. If it be taken that Mr. Gavin's cows were about three years old at the beginning of their first lactation, all three sets show that cows are at their best about their eighth or ninth year, but are only slightly better then than in their seventh. Therefore, since Mr. Gavin's cows decline in number after their seventh year, we shall take that year as nominally the best. Then, by calling the yields in that year 100 and raising the others by proportionate numbers, we shall be able to compare the three sets of data with each other. So arranged, the comparative yields are as follows:

	2 years old	3 years old	4 years old	5 years old	6 years old	7 years old
London Dairy Show Cows	—	69	83	89	97	100
Mr. Gavin's	—	61	83	92	97	100
Dr. Pearl and Mr. Miner's	75	77	84	91	97	100

Thus the only discrepancy is as to two and three-year-old cows. When plotted out, the curve which results from Dr.

Pearl and Mr. Miner's figures shows a clear break away at its lower end which is perhaps capable of explanation. It used to be fairly common for Ayrshire breeders to give young heifers a long rest at the end of their first lactation, and, since they represent the average for the whole lactation, not the maximum at the flush, Dr. Pearl's figures may readily be too high for the early years. Mr. Gavin's first lactation cows showed considerable variations, and, in discussing these, he remarked that "differences in feeding and general treatment and, most of all, in age, must influence very greatly the first lactation yield." Thus, as heifers' ages vary between thirty and thirty-nine months at their first calving, we shall take the figure 66, which is midway between Mr. Gavin's and that for the London cows, and say that it must be regarded as liable to vary between 60 and 70 according to the age of the heifer. And we shall take the figures for succeeding lactations as 83, 92, 97, 100. Thus, to estimate her capacity when she comes to her nominal best, the cow's maximum in her first lactation is to be multiplied by 1.5 (but variable), in the second by 1.2, in the third by 1.1 and in the fourth by 1.03. This proposal is expressed in the diagram on page 100.

With these figures and the records of her milk-yield while it is at the flush, it is possible to say, shortly after she has calved, whether a heifer should be retained for the production of calves and milk or prepared for the butcher. If a heifer's daily yield reaches an average of three to three and a half gallons at the maximum, it may reasonably be expected, no untoward circumstances intervening, to reach four and a half to five and a half gallons when she is seven years old, and that she will then be a 900 to a 1,100-gallon cow. If, however, it reaches only a gallon and a half at the maximum, it may not be expected to reach much beyond two and a quarter gallons when the heifer is full age, and that she will then be only a 450-gallon cow. As to the retention of the former and the rejection of the latter of these two heifers, there can be no doubt whatever. The former will return a profit, the latter, unless food and labour are very cheap and milk or milk products very dear, is unlikely to pay her way. It is difficult to fix a limit which shall separate the retainable from the rejectable—the farmer who has a high proportion of good cows and heifers will naturally take a higher limit, while he who has a low proportion must perforce take a lower—but it may be said, with reasonable safety, taking both profits and inheritance of milk yield into consideration, that no full age cow should have a lower capacity than seven hundred gallons, and, therefore, unless her maximum rises beyond two and a half gallons, no heifer should be retained for the production of calves and milk.



But the figures which show how milk yield rises with the cow's age can be used for a still more important purpose, namely to determine a bull's capacity to get or not to get high-yielding daughters. Unfortunately this cannot be done till his first crop of daughters come into milk and he himself is about five years old. It is a long time to wait, and many farmers object to keeping old bulls, still more to keeping a bull in the same herd for four years. Yet, till these objections vanish and bulls are kept alive either in one herd or in more till their grade can be determined, there can be little certainty of raising high-grade milking cows. The son of a 1,000-gallon cow may not be a 1,000-gallon bull, still less the grandson. The son of a 1,000-gallon cow and a sire which is also the son of a 1,000-gallon cow stands a higher chance of being a 1,000-gallon bull, but, even in his case, there is no certainty. Nor will there be till the parents on both sides—both sires and dams—are both proved to be of the highest grade.

But how is this to be accomplished? It is not very likely to be accomplished by using the sons of low-grade cows, no matter what their milk or "paper" pedigree. Little is likely to be gained by keeping such animals alive. It has more chance of being accomplished through the sons of middle-grade cows, but the chances are higher with the sons of 1,000-gallon cows, and highest with sons of 1,000-gallon cows and sires which are again the sons of other 1,000-gallon cows. Bulls of the last two categories especially should every one be kept till their grade is determined, and, if it be proved to be the highest, their lives should then be prolonged till nature itself takes them away.

The determining of a bull's grade is not a very complicated matter. The high-grade bull gets high-grade daughters with high-grade cows, high and middle grade daughters with middle-grade cows, and middle-grade daughters with low-grade cows. The middle-grade bull gets high and middle-grade daughters with high-grade cows, all three grades with middle-grade cows, and middle and low-grade daughters with low-grade cows. The low-grade bull gets high-grade daughters with no kind of cow.

But it must not be assumed that what we have called the 1,000-gallon cow, which may yield from 900 to 1,100, even, in exceptional cases, 1,200 gallons, is the limit. The records among British breeds may not suggest a higher grade, but recent accounts of the yields of Friesian cows suggest that, among them, there may be a still higher grade. If this be so, it will then be for the British cow breeder to consider his future policy. If stock of this still higher grade are to be found in his own breeds, the rest can be graded up. If not, he may have to consider whether he will discard his own breed for, or cross it with, the Friesian.

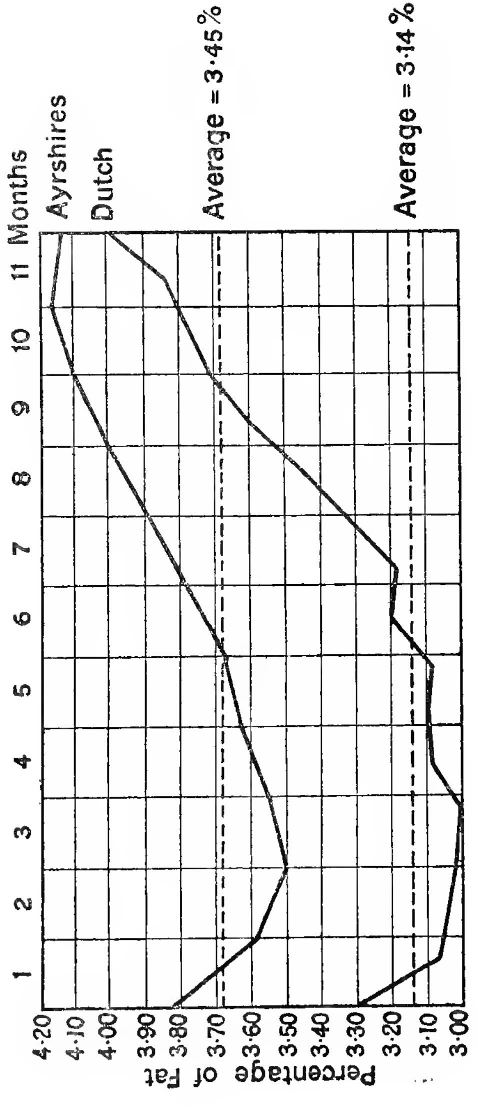
If it be agreed that milk is important for the farmer who rears young stock by suckling, whether they be calves or any other kind of animal, his problem is just the same, namely, to find the sires which leave good milking daughters: only his method is to identify the sires by the way in which their daughters rear their young.

Use and wont and the law of the country do not strongly encourage the cattle breeder to raise cows which shall give milk of higher quality. As a rule, the consumer gives no more for milk containing four per cent of butter fat than for milk containing three, and the law is satisfied if the milk contain not less than three. Nor does the price of cheeses, equally well made otherwise, rise and fall directly as the fat within them. The present custom, which pays little heed to quality, would be unfair, even did milk contain only fat and water, but, since it also contains albumen and sugar, usually in proportions which rise and fall with that of the fat, and, since 7 pounds of 5 per cent milk contain as much fat as 10, and as much solid food as 11½ pounds of 3½ per cent milk, the custom becomes pernicious. Not only so, but, as the cost of producing fat falls as the cow's capacity to produce it rises, just as the cost of producing milk itself falls with the rise in the cow's capacity, the present custom of selling milk by quantity alone does not tend towards economic production. Meantime, if only in their own interest, butter-producing farmers would do well to improve the capacity of their cows to give milk of higher quality, and, when the demand for better milk arises, be in a position to sell to the milk seller the cows he will then require.

The usual method of determining the average quality of a cow's milk is to sample and analyse at stated intervals throughout the lactation period. Daily tests give the accurate figure, of course, but sufficient accuracy is obtained even by monthly tests. Equal accuracy may be obtained, however, with still less labour, from the average of four tests made on successive days, when the cow is from seventeen to twenty-six weeks calved. The fat content falls for the first month or two, then rises slowly for the next four or five months, more rapidly towards the end. Near the twentieth week it is at the average for a whole normal lactation, as may be seen by the diagram on page 104, taken from Professor Nils Hansson's "Utfodringslära," which shows the fat content curve of two herds—an Ayrshire and a Dutch—throughout a lactation, at two Swedish stations.

This finding was confirmed recently, with cross-bred Shorthorn cows, at the Albert Agricultural College, Dublin, by Mr. Edmond Sheehy, who found that, though fat content is liable to daily fluctuations, a test carried out for four successive days, when the cows are from seventeen to twenty-six weeks calved, eliminates these fluctuations and gives the average fat content for the whole lactation, with a probable error of less than ten per cent. The test, however, must not be made during the first six weeks the cows are on pasture nor during the first three they are back again in the house, for, during these periods, the daily fluctuations are very great and are not always compensated by contrary fluctuations the following day, as they usually are at other times.

Perhaps the proportion of unprofitable to profitable hens is as high as that of unprofitable to profitable cows, but, thanks to Dr. Raymond Pearl's brilliant discovery and to the fact that it is now known and used by many breeders, the proportion of unprofitable hens is falling. Hens are of three grades: the first, provided they are hatched in time, lay from 170 to 220 eggs in their first laying season, the second from 90 to 120, the third less than 60. Provided they are hatched early, the first grade hens can be identified in late autumn or early winter, for they will then begin to lay at the rate of four to five eggs a week. The middle-grade may either begin then and lay at the rate of three a week, or wait till near the opening of spring and then lay at the higher rate. The third grade will not lay till spring. But, contrary to the usual rules of inheritance, hens have very little to say to their daughters' egg-laying faculties, the chief of which comes to them from their sires. The hen, though she have it within her and, by having it, be a 200-egg hen, may hand this faculty down to her sons but not to her daughters, for she has within her at the same time a low-producing recessive factor, which is inseparable from


Months
1
2
3
4
5
6
7
8
9
10
11
Ayrshires
Dutch
Average = 3·45 %
Average = 3·14 %
Percentage of Fat
4·20
4·10
4·00
3·90
3·80
3·70
3·60
3·50
3·40
3·30
3·20
3·10
3·00

the factor which determines her sex, and must be handed on to her daughters along with the sex factor itself and the other factors which produce the usual sex characters. Thus, to have 200-egg daughters, we must first find 200-egg fathers, and, since the hens may be hybrids, the fathers must be pure for the high-laying factor.

It may be difficult to find 200-egg fathers, for, as yet, they are not too numerous, but, when found, the way to reproduce them, as shown by Dr. Pearl, though difficult at the start, is perfectly clear and eventually easy. The outstanding feature of a pure 200-egg cock is that his daughters, illness, poor feeding, or other inhibiting factor not intervening, are all 200-egg pullets. But how is he to be reproduced? There is no hope in mating him with 60-egg hens, some with 100-egg, but most with 200-egg hens. He may be reproduced with one variety of the middle-grade hen, but that variety is hard to identify from the others. There are two varieties of 200-egg hens: one which is pure for the remaining egg-producing factors, the other not pure. The former leaves no low-grade daughters with middle or lower grade cocks, the latter leaves some low-grade daughters with most middle-grade and every low-grade cock. Thus, the breeder who would make absolutely sure must first find both tested cocks and hens: the former by their having left only 200-egg daughters with medium or low-grade hens, the latter by their having left no low-grade daughters with low-grade cocks. Making sure involves trouble and patience: trouble in trap-nesting every hen and, possibly, in finding a low-grade cock, and patience in waiting for the result: but, once they have been proved to be such, pure 200-egg hens and cocks will reproduce themselves till crossed again with inferior stock. The breeder who would avoid some of the trouble and be too impatient to wait for the result of the test may go on using untested 200-egg hens and cocks and hope for the best. Occasionally, by chance, he may find it, but his trouble is still to identify it when found.

It is common to speak of beef breeds, milk breeds, and butter breeds among cattle and of laying breeds and table breeds among poultry. These adjectives are partial misdescriptions. There are high-grade milk cows and butter cows in most beef breeds, high-grade beef cows and butter cows in so-called milk breeds, and high-grade milk cows in butter breeds. There are also high-grade laying hens in table breeds. What should be said is that beef breeds contain a higher proportion of beef animals, milk breeds of good milkers, butter breeds of butter cows than the others, and that laying breeds contain a higher proportion of good layers, table breeds of good table fowl.

CHAPTER VIII

FEEDING

THE commonest error in stockfeeding is underfeeding: sometimes in giving too little to eat, more often, perhaps, in giving plenty to eat but too little nutriment. So long as the grain and root farmer's chief object is to convert straw and roots into manure and it is not easy for him to find a second supply of stores about midwinter, the cattle in his possession must consume rations which are comparatively inefficient and fatten slowly. So long also as many fatteners will only have well-sized bullocks and calf rearers keep poor cows and rear and winter their calves so badly that they cannot reach the fattening size when they are about eighteen months old, the present system of keeping growing cattle waiting, idling their time, till the fattener wants them, is likely to continue.

Four different kinds of men are immediately concerned in the industry: the rearer of the calves, the raiser of the pasture, the grazier, and the fattener. Two or more may be rolled into one, as, for example, the raiser of the pasture and the grazier, but the calf rearer's main object is to produce butter, the grass raiser's to rent his pasture well, either to himself or some one else, the grazier's to buy young stores cheap and sell older ones dear, the fattener's to convert straw and roots into manure. The bullock is of interest to the grazier only. As yet nobody is seriously dissatisfied, but, when the calf rearer begins to consider his own and his family's labour and the profits he might have from his calves, if they were better reared, and the pasture raiser discovers the poor returns he gets from pasture as compared with what he might get, on his better land, at any rate, from other crops than pasture, it is possible some parts of the country may think of another policy. In the meantime, the parts of the country which rear their calves badly have only to compare their prosperity with that of those which rear them well.

Bullocks of the larger breeds which are well reared as calves and well fed, though not forced, later, make an average increase of nearly two pounds a day till they are about two years old. Then, the rate of increase declines till, when they are between three and four years old, it ceases altogether. The rate of increase for similarly bred and reared heifers is from fifteen to twenty per cent less. Thus, allowing for his initial weight, a good bullock may weigh just over six to seven hundredweights at twelve months old, twelve to thirteen at twenty-four and fifteen to seventeen at thirty-six. It is obvious, therefore, if profit is to be chiefly considered, that, since his maintenance requirements are still growing and his rate of increase beginning to decline, such a bullock should go to the butcher somewhere near two years old, at the latest.

Calves which are afterwards to make two pounds a day or more are usually suckled, one to young or low-yielding cows, two or more to full-grown high-yielding cows. The best breeders prefer to have their cows calving in winter, because the first two calves may be replaced by one or two others, when the pasture springs. A heifer is rarely asked to rear more than one calf in her first reason, but, if she shows then that she is to be a good milker, she may be asked to rear two calves in the next winter, and have one withdrawn and the other left, or both withdrawn and another put on, for the following summer. Full age cows of high yield rear two calves during the winter and two others during the summer. Late calved cows seldom rear a second pair of calves. The winter calves do not all make equal progress, of course, and it is almost impossible to prevent their having a slight setback at weaning, but, if weaning comes with the beginning of the grazing season and the calves have been accustomed to hay and nutted cake, or early cut green rye grass, they soon recover on good young pasture. Calves which are to maintain their progress need cake or cake and grain, beginning with half a pound and rising to two, as the pasture fails in autumn. Careful rearers supplement the failing pasture with cabbages or vetches or both till the early turnips are ready, to which the calves are gradually trained when housed for the winter. By this time, the more forward bullocks weigh about five hundredweights, and their ration, during the winter, rises from three to five stones of roots, three to five pounds of cake and grain, and hay, with or without an admixture of straw. At housing time, the younger calves are about two hundredweights lighter, and, throughout the winter, their ration lags behind the others by about a stone of roots, a couple of pounds of hay, and a pound or two of concentrates. With treatment such as has been indicated, the most forward animals are ready for the butcher almost at any time, but, the prevailing policy is a lighter winter ration of hay and straw, roots, and a pound or two of concentrates, with intensive feeding postponed till towards or after the end of the summer grazing.

But how are hand fed to be as well reared as suckled calves and be ready for the butcher in equal time? Little is to be gained by having the calf hand fed upon whole milk, for it might as well do its own milking and, so, save expense. The problem is: how is the calf to be reared upon separated or skimmed milk and butter fat substitutes? On this question, unfortunately, there are few data. There have been experiments in which different substitutes have been tried against each other, in which the calves made gains similar to those made by the ordinary butter producer's calves, but none in which an attempt was made to find out how calves should be fed, if they were to do as well as suckled calves. In several of those experiments, the calves made two pounds a day, but, unfortunately, the complete rations were not recorded, probably not even measured. The experimenters faithfully record the kinds and quantities of milk and fat substitutes, but, though they tell us that the rations contained such other things as hay, fingered carrots, or turnips, and pasture, the quantities of those other things are not mentioned. Thus, these experiments are only of little use for our present purpose.

A basis from which the needs of calves may be deduced may be found, however, in the English and Scotch fattening experiments. It has already been shown, by an approximately accurate method, that the rations varied in efficiency. If we set down the food units consumed in a few of the most efficient rations, subtract the food units required for maintenance, and divide the difference by the daily increase, the result gives the number of food units required to produce a carcase increase of one pound. This is done in the following table :

Live weight group	Food units consumed	Food units required for maintenance	Difference	Daily gain in lbs.	Food units to produce one pound of increase
cwts.					
6	11.37	4.45	6.92	2.07	3.34
7	14.06	5.2	8.86	2.05	4.32
8	16.34	5.95	10.39	2.42	4.29
9	19.30	6.7	12.60	2.42	5.20
10	16.41	7.45	8.96	2.48	3.61
11	16.68	8.2	8.48	2.35	3.60
—	16.06	8.2	7.86	2.54	3.09
12	18.19	8.95	9.24	2.30	4.02
—	17.95	8.95	9.01	2.38	3.79
—	19.58	8.95	10.63	3.13	3.39

According to these figures it is evident that, after a portion of it has supplied what is necessary for maintenance, the remainder of a highly efficient ration produces a pound of carcase increase for every 3.1 to 3.8 food units it contains. It is equally obvious that a more definite figure cannot be given, without further investigation; but to have one to work with which shall not be an under-estimate, we shall take it that, after maintenance has been supplied, a pound of carcase increase is produced by about every 3.3 food units in the rest of a very well " balanced " ration.

But what about the milk stage ? On the assumption that milk is likely to be a more efficient ration for calves than a mixture of long fodder, roots, and concentrates for older animals, it might reasonably be expected that not more than three units, that is nine pounds of milk, should be necessary to produce a pound of increase. If the maintenance line for smaller animals, which allows for their requiring more for maintenance as they decrease in size, be produced to the left, it shows that the maintenance requirements of a calf are .7 of a food unit at one hundredweight, 1.08 at one and a half hundredweights, and 1.45 at two. But, if 3 pounds of milk are to produce as much as 3.3 pounds of a mixed ration, the maintenance figures for milk should therefore be as follows:

at 1 cwt. live weight $\frac{3}{3.33} \times .7$ namely .63 unit
at 1½ ,, ,, ,, $\frac{3}{3.33} \times 1.08$,, .93 ,,
at 2 ,, ,, ,, $\frac{3}{3.33} \times 1.45$,, 1.32 ,,

Thus, a calf of the larger breeds, about three weeks old, weighing about a hundredweight, should require 10.89 pounds of milk (.63 plus 3 units) to make one pound of carcase increase, 19.89 pounds (.63 plus 6 units) to make two, and, if this be possible, 28.89 (.63 plus 9) to make three. When it is above the average quality, slightly more, when below, slightly less milk will be required. This estimate is substantially confirmed by two investigations, one at the Missouri Experiment Station, the other in Germany. The Missouri experiment, as recorded in Professor Eckles's "Dairy Cattle and Milk Production," page 201, shows the milk required to make a pound of gain, maintenance included, during the first thirty days of the calves' lives, when their average weight is under a hundredweight, as follows:

	Number of calves	Average weight at birth	Average weight at 30 days	Average daily gain	Pounds of milk to a pound of gain
Jerseys	10	49 lbs.	88.9 lbs.	1.30 lbs.	9.42
Holsteins	8	38 ,,	127 ,,	1.46 ,,	10.02
Ayrshires	2	70 ,,	107 ,,	1.23 ,,	9.31

The German investigation, which is reported in "Landwirtschaftliche Jahrbücher" for 1909, pages 919 *et seq.*, by

Professor Hittcher, was part of a larger investigation on the elimination of tuberculosis from a herd of Holstein cattle, carried out under Professor Ostertag, at Kleinhof-Tapiau, the home farm of a German landowner. The calves bred on the farm and others purchased in the neighbourhood were fed upon whole milk alone or upon whole milk plus small quantities of liquids and powders, of which one was formalin, which were not expected to affect the nutritive powers of the milk, but prevent the calves from becoming tuberculous. Because of the cost, the landowner made it a condition that no calf was to get more than ten kilogrammes, that is twenty-two pounds, of milk in the day. The following table gives the average weights of 61 calves, successfully reared, the milk consumed per day, the daily gain and the milk required to produce a pound of gain :

	Average initial weight	Average weight 70 days later	Average daily milk consumption	Average daily gain	Pounds of milk to produce a pound of gain
	lbs.	lbs	lbs.	lbs.	lbs.
39 male calves	95.15	214.65	18.35	1.71	10.75
22 heifer calves	92.55	207.90	19.37	1.65	11.77

An unusually instructive experiment was carried out at the Royal Agricultural College, Hohenheim, in Würtemberg, in the year 1909–10, by Dr. Gustav Fingerling, and reported in vol. lxxiv of " Landwirtschaftlichen Versuchs-Stationen," which, because the daily gains are not reported, does not directly confirm our figures as to how much milk is required for a pound of gain, but shows how much whole milk may be consumed by large-sized calves, how much muscular tissue is produced, and how whole milk may be economically utilized. The calves were Simmenthalers, a dual purpose Swiss breed, perhaps slightly heavier than the Shorthorn when full grown and less rapid in its early growth.

The outstanding feature in the growth of a well-fed calf is the constant and even increase of muscular tissue or flesh, of which about 77 per cent is water, the remainder albumen, excepting for a very small quantity of mineral salts. Of the albumen, 16.67 per cent is nitrogen. Thus, if we know how much nitrogen an animal has retained in his body in a given time, by multiplying the quantity by $\frac{100}{16.67}$, that is by six, we can tell how much albumen, and by $\frac{100}{16.67} \times \frac{100}{23}$, that is by 26.1, how much flesh has been laid up in its body in the same time.

Immediately after calving, the cow's milk is about four times as rich in albumen as when it has dropped to the normal,[1] and the calf is able to make as much flesh upon this early milk as it can upon larger quantities of normal milk. Not only so, but, while a week old calf is able to convert into flesh from eighty to ninety per cent of the albumen in the milk it consumes, this ability gradually declines, and, when it is six or seven weeks old, the same calf needs about a half more milk to lay on the same normal quantity of flesh. If it had nothing else to do than lay on flesh, the calf would continue to be satisfied, from the age of five or six weeks onwards, with the same quantity of milk, but it has to keep up heat and movement in a body which is constantly increasing in weight, and perhaps store up reserve energy in the form of fat. Thus, the calf needs more and more food of the energy-producing kinds which, under natural conditions, are drawn

[1] Dr. Chas. Barthel, quoting from Engling, gives the following as the composition of colostrum and normal milk:

	Immediately after calving	At 10 hours	At 24 hours	At 48 hours	At 72 hours	Normal milk.
Water	73.17	78.77	80.63	85.81	86.64	87.75
Casein	2.65	4.28	4.50	3.25	3.33	3.00
Albumen and Globulin	16.65	9.32	6.25	2.31	1.00	.50
Fat	3.54	4.66	4.75	4.21	4.08	3.40
Milk sugar	3.00	1.42	2.85	3.46	4.10	4.60
Ash	1.18	1.55	1.02	.96	.82	.75

from grasses and clovers and other green herbage. Under artificial conditions, several things may happen. First: the calf may get no more, or even less milk, and no extra food. In that case, heat and movement, the first and imperative necessities, finding no other source, seize upon so much of the milk albumen as they require, and the calf, having less left over to convert into muscular tissue, falls off in its rate of growth. Evidence of this is found in the increased amount of nitrogen excreted in the urine. Carbonic acid, let off in the combustion of fats and carbohydrates, is excreted by the lungs; nitrogen, let off in the combustion of albumen, by the kidneys. Second: the calf may be given more milk. In that case, since it cannot all be converted into flesh, the surplus albumen is combusted to produce heat and movement, perhaps fat, and the nitrogen let off in the process is excreted through the kidneys. Third: the same or even less milk may be given and heat and movement and some flesh produced from other foods. In that case, the nitrogen excretion is not increased. These phenomena are illustrated by Dr. Fingerling's experiments, the essential details of which are to be found in the tables on pages 120 and 121. Five male calves were fed for three or four periods and rested in the intervals between. In the table, the rest periods are used to indicate the food given in the succeeding experimental periods.

It is obvious, since they can make flesh from nothing but albumen, that calves will not make the maximum growth unless fed with as much albumen as they require; and it is equally obvious that, if they get more albumen than they require, the surplus will go to the production of energy or the deposition of fat, or both—functions which may be more economically performed by fats and carbohydrates. Dr. Fingerling's experiments show that, when they have reached a certain size, which is somewhere between a hundredweight and a hundredweight and a quarter, ordinary milk alone does not supply the calves with sufficient fat and sugar to produce the necessary energy—and perhaps deposit some fat—and some part of this function has to be performed by the albumen. All five experimental calves were capable of putting on just over two pounds of flesh—not fat and flesh, not total increase, but flesh alone—in the day. When seven days old, calf A consumed 15.95 pounds of milk and put on 2.03 pounds of flesh, while the decomposition of previously formed muscular tissue is represented by 4.20 grammes of nitrogen excreted in the urine. With the milk increased at the rate of .33 pounds a day, the calf consumed 17.60 pounds, when twelve days old, and the excretion of nitrogen rose to 8.50 grammes. During the last day or two, the flesh increase shows signs of falling off, and this, together with the rather large concurrent increase of execreted nitrogen suggests that the fat and sugar in the milk may already be deficient in quantity. In the second experiment, during which the same calf ages from sixteen to twenty-one days, the milk stands at 17.60 pounds, but butter fat and milk sugar are added equivalent in energy-producing power to—i.e., isodynamic with—a daily increase of .33 pounds of milk. Thus the calf gets no more albumen than when twelve days old, but, to supply the energy which his increasing bulk requires, a daily increasing quantity of energy-producing ingredients in his food; and the production of flesh and excretion of nitrogen remain nearly constant.

Calf B, when fifteen days old, is fed with 19.14 pounds of milk, that is just a trifle more than would have been fed to calf A at the same age, had his milk been constantly increased; and the result is similar: 2.12 pounds of flesh gained, and 8.25 grammes of nitrogen excreted; but, for the next eleven days, he gets a daily increase of .33 pounds of milk, and, while the flesh gain remains the same, the nitrogen excreted gradually rises. The albumen is more than is necessary for flesh production, and the surplus is used for the production of energy, perhaps for the deposition of fat.

Calves E and F, from twenty-two days old onwards, got 22 pounds of milk a day, without increase, but, having less total food and less fat and sugar than B, and being older and heavier, need so much more of the albumen to make up for the lack of fat and sugar that their daily increase in flesh grows less and their nitrogen excretion greater.

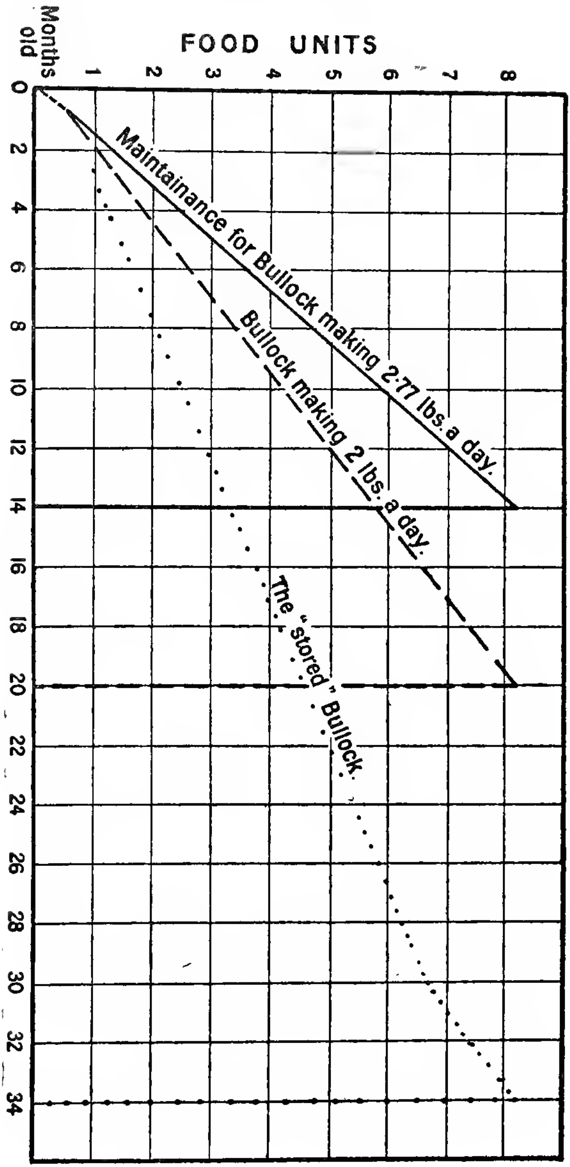
Calf D, on the other hand, is given less milk and therefore less albumen than B, E, or F, but a daily increasing quantity of fat and sugar is added, and, having sufficient energy-producing matter in his food, the whole of the albumen goes to the production of flesh and the nitrogen excreted is only what comes from the breaking down of previously formed tissue. In this case, the albumen, on the one hand, and the fat and sugar on the other, have their full effect, and there is no waste.

Some of the remaining experiments confirm these results, but others show that, though there may be no waste of albumen when the milk does not exceed 19 or 20 pounds, the calf's growth is less the more the milk falls below this quantity. This is to be seen from the following table:

Calf F made full growth upon only 11 pounds of milk; but sufficient egg albumen was added to make up for the deficiency in milk albumens.

Calf	Experiment	Milk fed	Nitrogen in the milk	Average daily increase in flesh
		lbs.	grammes	lbs.
A	2nd	17.60	44.85	1.98
B	2nd	16.50	39.54	1.62
B	3rd	16.50	39.51	1.48
E	2nd	11.00	26.87	.96
E	3rd	11.00	26.48	.84
A	3rd	8.80	22.48	.87

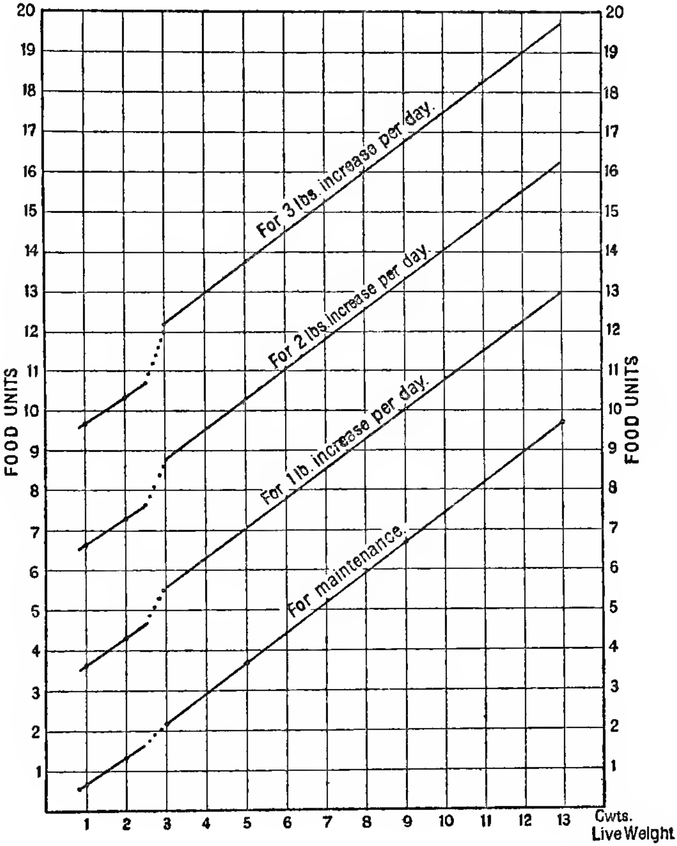
Before considering how we are to be guided by all this and any other experimental and experiential information, it will be well to look more closely into the part played by the maintenance portion of the rations in rapid as against protracted production. A large proportion of the bullocks fattened in Britain come to the butcher at about eleven hundredweights: a weight which those of the larger breeds and their crosses may attain, according as they are treated, as early as fourteen or fifteen months and as late as three or four years. Very few bullocks come to this weight at the minimum age, for such as get the start which would enable them to do so are usually turned into veal; but, at the spring sales, a considerable number of the young bulls of the larger breeds have attained this weight and are not over thirteen


FOOD UNITS
Months old
1
2
3
4
5
6
7
8
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
Maintainance for Bullock making 2·77 lbs. a day.
Bullock making 2 lbs. a day.
The "stored" Bullock.

or fourteen months old. Allowing their initial weights to have been 70 pounds, the thirteen months old bulls have increased at the rate of 2.98 pounds a day, the fourteen months old ones at 2.77 pounds; and what is done by bulls may be done by bullocks. Bullocks which are suckled or equally well reared and afterwards treated so that their average daily increase is about two pounds, attain a weight of eleven hundredweights at about twenty months old. The ordinary "store" bullock, which is reared upon separated milk and fat substitutes, and not well treated during the two following winters, weighs about nine hundredweights at thirty months old, and comes up to eleven hundredweights after three or four months of more or less intensive feeding. The number of food units which each of these three kinds of bullock consumes in mere maintenance with very efficient rations is shown in the diagram on page 117. The total numbers are, for the first about 1,827 units; the second 2,600; and the third, 3,910; yet each brings to the butcher the same quantity of beef!

Having found that, after the requirements for maintenance have been satisfied, about 3 units of milk, i.e. 9 pounds, and 3.33 units of a very efficient ration of long fodder, roots, and concentrates produce a pound of carcase increase, we may set out how animals of various ages and rates of increase may be rationed. To avoid calculations, we shall first express the requirements in food units diagrammatically, and, as fewer food units are required when milk is fed than later, the period of transition from milk to a mixed ration is indicated in the diagram by dotted lines.

Since, at pre-war prices, the skilful butter-maker can extract over fourpence worth of butter from a gallon of normal milk and have the skimmed or separated milk left over, while the calf cannot make fourpence worth of carcase from the same quantity of milk, it is obvious that calves are not likely to be fed upon whole milk at other times than when it is an absolute necessity, unless when they are expected to bring considerably more than carcase value or the milk cannot be turned to more profitable account. Bull calves which increase by nearly three pounds a day, when reared by their own dams, are seldom the sons of heifers, never of low-yielding cows, but almost invariably sons of exceedingly good heifers or of high-yielding older cows. In cases, while the milk is at the flush, the calves are unable to consume it all—sure signs of a good cow—and the surplus has to be drawn by hand; but, as the calves grow bigger and older, hand milking becomes no longer necessary, and by the time



Age in days.	CALF A.				CALF B.				CALF E.				CALF F.				CALF D.			
	Milk fed lbs.	Containing Nitrogen grammes	Increase in flesh lbs.	Nitrogen excreted grammes.	Milk fed lbs.	Containing Nitrogen grammes.	Flesh increase lbs.	Nitrogen excreted grammes.	Milk fed lbs.	Containing Nitrogen grammes.	Flesh increase lbs.	Nitrogen excreted grammes.	Milk fed lbs.	Containing Nitrogen grammes.	Flesh formed lbs.	Nitrogen excreted grammes.	Milk fed lbs.	Containing Nitrogen grammes	Flesh increase lbs.	Nitrogen in urine grammes.
	Milk only.																			
7	15.95	39.65	2.03	4.20																
8	16.28	40.47	2.02	4.50																
9	16.61	43.18	2.11	5.20																
10	16.94	43.11	2.07	5.55																
11	17.27	43.80	2.04	7.06																
12	17.60	44.88	2.01	8.50																
	Milk, plus a daily increase of butter fat and milk sugar equal to .33 lb. of milk.				Milk only.												Milk plus as much increasing milk sugar and butter fat as would be equivalent in energy production—as would be *isodynamic* to—.44 lbs. of milk.			
15					19.14	47.41	2.12	8.25									19.8	46.98	2.18	7.03
16	17.60	45.60	2.01	8.06	19.47	46.64	2.04	9.10									19.8	48.68	2.13	9.30
17	17.60	44.08	1.94	7.85	19.80	48.24	2.09	9.45									19.8	47.33	2.23	6.33
18	17.60	45.03	1.96	8.63	20.13	50.60	2.17	10.20									19.8	47.97	2.12	9.16
19	17.60	44.47	2.01	7.32	20.46	49.29	2.14	9.85	Milk only.				Milk only.				19.8	46.52	2.25	4.75
20	17.60	45.59	1.99	8.39	20.79	51.12	2.18	10.38									19.8	46.89	2.19	8.10
21	17.60	44.31	1.98	7.22	21.12	50.50	2.09	11.73	22	52.10	2.17	12.12	22	53.40	2.23	12.62	19.8	48.33	2.24	6.93
22					21.45	52.06	2.22	10.09	22	54.15	2.21	13.49	22	54.80	2.35	11.76	19.8	45.72	2.11	7.31
23					21.78	50.48	2.13	9.76	22	53.83	2.13	15.00	22	52.76	2.17	13.49	19.8	48.68	2.20	7.90
24					22.11	53.06	2.13	12.25	22	54.60	2.18	14.62	22	53.00	2.09	14.82	19.8	47.16	2.13	7.85
25	Milk plus increasing butter fat and milk sugar.				22.44	53.14	2.04	13.74	22	53.30	2.04	15.92	22	54.20	2.10	15.07	19.8	46.98	2.14	7.37
26					22.77	52.58	2.09	12.65	22	52.87	2.00	16.06	22	52.80	1.92	16.80	19.8	46.92	2.18	6.19
27	8.80	22.72	.88	5.04	23.10	53.66	2.10	13.09	22	52.98	1.91	17.24	22	54.70	1.97	18.46	19.8	46.80	2.06	8.80
28	8.80	22.48	.86	5.02					22	50.30	—	—	22	54.20	2.01	17.36	19.8	48.87	2.25	7.12
29	8.80	22.40	.87	4.98					22	52.20	1.89	17.82	22	53.70	1.88	18.70	19.8	49.58	2.18	8.98
30	8.80	22.16	.86	4.73					22	54.75	2.01	17.14	22	53.20	1.78	20.20	19.8	49.40	2.22	7.79
31	8.80	22.32	.83	5.30					22	52.10	1.82	18.10	22	54.90	1.83	21.08	19.8	48.41	2.13	8.68
32	8.80	22.80	.82	5.23	Milk plus increasing butter fat, milk sugar and starch.				22	53.40	1.74	20.23					19.8	48.05	2.12	8.87
33									22	53.25	1.73	20.69					19.8	47.60	2.19	6.96
34									22	52.70	1.63	22.15					19.8	47.15	2.10	7.73
35					16.50	39.07	1.64	6.39	22	53.85	1.64	23.38					19.8	46.79	2.07	8.13
36					16.50	40.57	1.73	6.41	22	53.30	1.59	23.85					19.8	48.77	2.12	8.85
37					16.50	40.64	1.70	6.63	22	54.10	1.60	24.12	Milk plus 200 grammes egg albumen (23.72 nitrogen), and increasing butter fat and milk sugar.				19.8	49.31	2.15	8.71
38					16.50	39.97	1.65	7.18									19.8	47.82	2.19	7.23
39	Milk only.				16.50	40.94	1.68	7.60									19.8	48.95	2.12	8.94
40	25.30	64.16	1.94	27.86	16.50	39.44	1.58	7.89									19.8	48.50	2.16	7.86
41	25.63	63.48	1.97	26.98	16.50	38.70	1.46	8.90									19.8	45.89	2.00	7.95
42	25.96	64.07	1.99	26.91	16.50	40.19	1.62	7.68					11	50.57	2.23	6.53	19.8	46.34	2.10	7.14
43	26.30	65.72	1.95	29.07	16.50	30.00	1.62	7.05					11	50.12	2.19	6.96	19.8	46.79	2.07	7.47

46	16.50	39.22	1.53	8.08					11	49.82	2.09	9.57
47	16.50	39.89	1.65	7.33					11	50.22	2.13	9.49
48					Milk plus increasing butter fat and milk sugar.				11	50.32	2.22	7.34
49									11	49.57	2.07	8.94
50									11	49.92	2.16	7.81
58					11	26.50	1.00	6.22	Milk plus 225 grammes egg albumen (26.69 nitrogen), and increasing butter fat and milk sugar.			
59					11	27.10	.96	7.05				
60					11	26.40	.95	6.88				
61					11	27.35	1.03	6.68				
62					11	27.10	.97	6.83	11	52.28	2.12	10.83
63					11	26.85	.99	6.48	11	53.86	2.15	11.40
64					11	26.60	.92	6.76	11	53.38	2.19	10.22
65					11	27.45	.96	6.58	11	52.68	2.12	10.96
66					11	26.45	.93	6.45	11	53.83	2.13	11.55
67									11	52.63	2.02	11.86
68									11	52.38	2.13	10.32
69									11	53.78	2.09	12.33
70	Milk plus increasing butter fat and milk sugar.				Milk plus increasing butter fat and milk sugar.				11	52.78	2.10	10.81
71									11	53.93	2.07	12.34
72									11	53.63	2.08	12.49
76	16.50	40.80	1.68	7.10	11	26.85	.95	6.91				
77	16.50	38.92	1.56	7.55	11	26.40	.82	8.10				
78	16.50	38.85	1.56	7.30	11	26.70	.83	8.08				
79	16.50	39.07	1.60	7.14	11	27.15	.88	8.11	Milk plus increasing butter fat and milk sugar.			
80	16.50	40.35	1.64	7.30	11	26.10	.82	8.12				
81	16.50	38.77	1.52	7.83	11	26.50	.82	8.16				
82	16.50	39.52	1.55	8.24	11	26.60	.82	8.02	22	54.00	2.15	13.12
83	16.50	38.62	1.59	6.88	11	25.86	.79	8.18	22	54.85	2.10	14.51
84	16.50	38.62	1.56	7.12	11	26.20	.81	8.35	22	53.18	2.12	12.08
85	16.50	41.73	1.66	8.33					22	53.90	2.09	12.61
86	16.50	40.50	1.60	7.98					22	52.85	2.07	11.86
87	16.50	38.25	1.48	8.16					22	54.90	2.07	13.79
88	16.50	39.60	1.54	8.40					22	55.20	2.06	15.12
89									22	54.36	2.04	14.46
90	Milk only								22	53.60	2.05	13.37
91									22	52.40	2.04	12.82
96	27.17	64.22	1.94	27.55								
97	27.50	67.25	2.12	27.86								
98	27.83	66.40	2.14	26.98								
99	28.16	69.50	2.30	26.91								
100	28.49	68.62	2.12	29.07								
101	28.82	69.16	2.10	30.33								
102	29.15	71.80	2.14	31.44	Milk plus increasing butter fat and milk sugar.							
103	29.48	68.06	1.80	33.35								
104	29.81	71.00	1.94	33.54								
117					22	53.84	2.08	14.25				
118					22	53.10	2.04	14.78				
119					22	52.43	2.00	13.98				
120					22	54.00	2.05	14.20				
121					22	52.90	1.95	14.43				
122					22	53.60	2.07	13.64				
123					22	54.95	2.05	15.27				
124					22	53.60	2.00	14.42				
125					22	54.12	2.02	15.28				

the milk yield has seriously declined, the calf is able to keep up his increase by consuming hay or pasture and any concentrates that may be offered him. The diagram shows that the calf's consumption of milk may sometimes be about forty pounds a day. When a second cow is put on to assist the dam, as her yield declines, an old calf may consume even more than four gallons of milk a day. The outlay which this method of rearing involves may be justified by the prices the calves bring, when they come to be sold, but the buyer who endeavours to infer the capacity of the dam from the calf's apparent progress and the calf's promise as a breeder, from the dam's inferred capacity, may have his judgment seriously obscured.

Breeders of calves which are eventually to be fattened for the butcher are satisfied with smaller daily gains at a much smaller cost. This is not because they produce milk at much smaller cost, but because their calves get less milk during the milk consuming period, and, in many cases, are weaned when much younger. Before weaning, they consume a greater quantity of foods which are cheaper than milk, and, afterwards, are forced to rely upon such food stuffs entirely.

The cost of rearing these calves depends, in the first instance, upon the cost of keeping the cows, which, though it cannot be determined with accuracy, may be discussed. The cows are pastured in summer, and fed upon roots and straw, sometimes hay, in winter. Only such as fall off seriously in condition, usually the best milkers, get concentrates. Thus, in winter, at any rate, few give milk to their full capacity. All full-grown cows on the same farm get about the same quantity of roots, younger ones not so many ; but, by cleaning out their fodder racks more thoroughly and having them oftener and more heavily replenished, the better cows get a larger supply of straw. Variations in food costs are, therefore, small in winter, but, through every cow, good and bad, having her will of the pasture, relatively greater in summer. Thus the food cost for the year may be estimated, roughly, as follows : the lower figures against poor heifers, the higher against the older and better cows :

		£	s.	d.		£	s.	d.
Roots ..	7 to 9 tons ..	3	10	0	to	4	10	0
Straw ..	30 ,, 40 cwts. ..	2	5	0	,,	3	0	0
Concentrates	0 ,, 1 cwt. ..	0	0	0	,,	0	7	6
Pasture ..	1¼ ,, 2 acres ..	2	10	0	,,	4	0	0
		£8	5	0	,,	11	17	6

Then, if we allow labour and other charges to be counterbalanced by the value of the manure and give each cow £2 for her share of the crop of living and healthy calves, we may say that heifers cost about £6 and the older and better cows about £10. Thus, if poor heifers give 300 gallons of milk, the single calves they rear consume six pounds' worth of milk at 4.8 pence (£6 ÷ 300), while, if the better cows give 900 gallons, each of the four calves they rear consumes, on the average, fifty shillings' worth of milk at 2.67 pence (£2 10s. 0d. ÷ 900) a gallon. Thus, even the rearer of suckled calves is at a great advantage in having good cows.

When we come to the rearing of calves upon skimmed or separated milk, we come to greater difficulties and greater room for improvement; and, unfortunately, we have few British experiments to give a satisfactory lead. British experimenters have not endeavoured to determine first the maximum increase which calves of the larger kinds could make, and, then, having done so, find out whether this increase could be produced by a ration of skimmed or separated milk and butter-fat substitutes. They have rather assumed two pounds a day to be about the maximum increase and, then, endeavoured to find the ration of separated milk and fat-substitutes which would produce it, or nearly produce it, at the cheapest rate. A good example of this kind of experiment was carried out by the Irish Department of Agriculture in the years 1901, 1902, and 1903. The rations and increases for 1902 and 1903 are given in the following table. The calves were from four to six weeks old and weighed about 140 pounds at the commencement of the experiments. They also had pasture in addition to the experimental rations.

RATIONS

					Weaning Period	
		First three weeks	Fourth to sixth weeks	Seventh to sixteenth weeks	Seventeenth and eighteenth weeks	Nineteenth and twentieth weeks.
Lot 1	Whole milk	15 lbs.	15 lbs.	15 lbs.	10 lbs.	5 lbs.
	Linseed cake	6 oz.	8 oz.	8 oz.	16 oz.	16 oz.
Lot 2	Separated milk	12.5 lbs.	12.5 lbs.	12.5 lbs.	7.5 lbs.	3.75lbs.
	Whole milk	2.5lbs.	2.5 lbs.	2.5 lbs.	2.5 lbs.	1.25 lbs.
	Linseed cake	6 oz.	8 oz.	8 oz.	16 oz.	16 oz.
Lot 3	Separated milk	15 lbs.	15 lbs.	15 lbs.	10 lbs.	5 lbs.
	Codliver oil[1]	2 oz.	2 oz.	2 oz.	2 oz.	1 oz.
	Linseed cake	6 oz.	8 oz.	8 oz.	16 oz.	16 oz.
Lot 4	Separated milk	15 lbs.	15 lbs.	15 lbs.	10 lbs.	5 lbs.
	Meal mixture[2]	4 oz.	6 oz.	8 oz.	8 oz.	4 oz.
	Linseed cake	6 oz.	8 oz.	8 oz.	16 oz.	16 oz.

DAILY GAINS

	First four weeks	Second four weeks	Third four weeks	Fourth four weeks	Fifth four weeks	Average over twenty weeks	Cost of experimental food per pound of gain[3]
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	pence
1902	1.80	2.06	2.24	2.12	2.19	2.08	4.07
1903	1.76	2.09	2.29	2.29	1.86	2.06	
1902	1.73	1.89	1.56	2.01	1.92	1.82	1.75
1903	1.69	1.49	1.98	2.22	1.17	1.71	
1902	1.58	1.72	1.62	1.84	1.95	1.82	1.62
1903	1.49	1.64	1.90	2.34	1.24	1.72	
1902	1.72	1.62	1.81	2.05	1.95	1.83	1.46
1903	1.61	1.81	2.12	2.48	1.44	1.89	

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[1] Fluid ounces.

[2] Two parts oatmeal, two Indian meal, and one flax seed.

[3] The prices were: whole milk, 4⅜d. a gallon; separated milk, 1d., and cod liver oil, 5s. 6d.; linseed cake, 8s. 9d. a cwt.; oatmeal, 12s.; Indian meal, 8s., and crushed flax, 17s.

If two pounds a day be the limit of increase for calves fed upon separated milk and butter fat substitutes, and, if the ration given to the fourth lot of calves in the Irish experiments can put on almost two pounds a day, at a cost of less than three halfpence a pound of increase, nothing more can be done than recommend that ration, till a better, cheaper, and equally efficient one be found. But, in view of the economic advantages of rapid growth, we might suggest the nature of the ingredients likely to be found in the most successful rations.

Since it starts with a small consuming capacity but a great power of converting the albuminoids in milk into flesh, and, since new milk, or colostrum, is highly albuminous at first, but comes down to the normal in four to six days, the calf must have its mother's milk for the first five or six days. At the end of that time, as Fingerling's figures show, the calf makes just over two pounds of flesh from about fifteen pounds of milk, but, as its power of converting albumen into flesh is declining and its weight increasing, the calf, to continue making the same quantity of flesh, must have its feed increased by about a third of a pound of milk a day, till it is about a fortnight old and the milk has risen to about twenty pounds, i.e. two gallons. From a fortnight onwards, the albuminoids in two gallons of milk are, apparently, sufficient.

It is obvious, if the calf is to make full growth, that the albuminoids cannot be cut down, and, if they are to be confined to their own special function, energy-producing substances must be added. Thus, the crux of the problem is: when may the butter fat be withdrawn from milk and other less readily digestible but cheaper things substituted, and, that settled, what are the most likely substitutes? As yet, neither of these questions has been clearly answered. Dr. Fingerling added butter fat and milk sugar when the calves were a fortnight old, but these additions, if well mixed, do not appreciably affect the digestibility of the milk. As, however, the calf begins to nibble hay, when it is about a fortnight old, it may be taken as being then capable of dealing with a small quantity of concentrated foodstuffs. Of the concentrates generally used, the most successful have been linseed, linseed cake, maize meal, and crushed oats. Barley and rye have been largely used, on the continent, and earthnut cake has been successfully used in Denmark. Of all these, the best, for its bulk, is linseed, and we shall continue for a week, therefore, to give the calf two gallons of whole milk a day and, to supply energy, an ounce of linseed, which is equivalent to about a third of a pound of milk, on the first day of the week, and, by adding another ounce every day, increase the supply to about half a pound at the end of the week. In the fourth week, we shall begin to substitute separated milk for whole, and add fat substitutes and other foods.

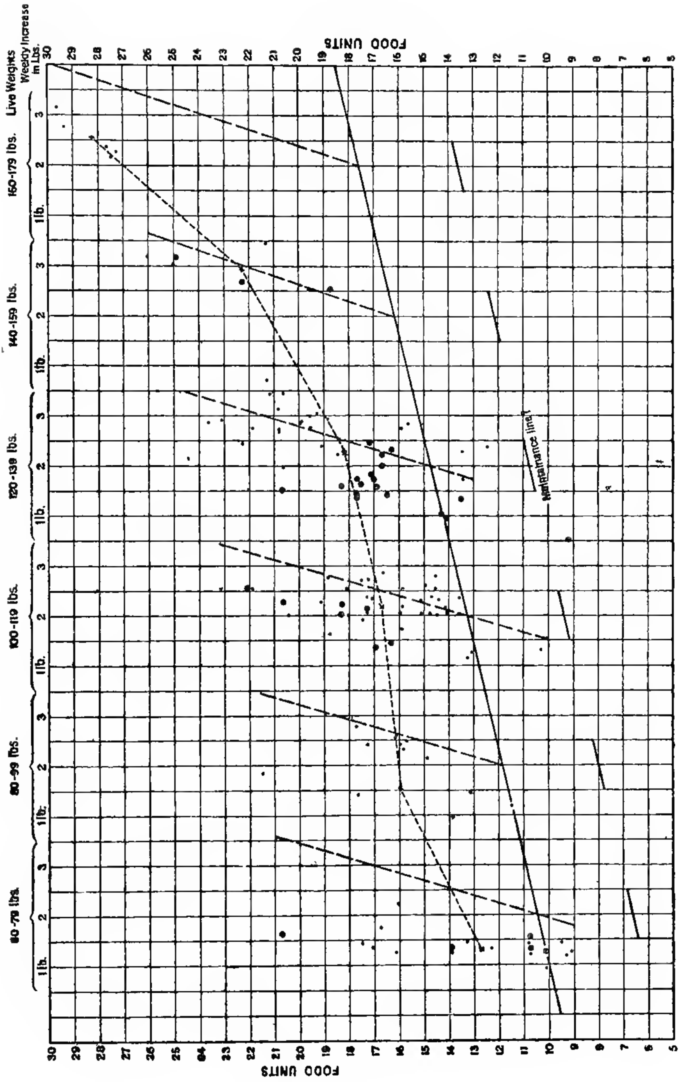
The table on next page shows the probable number of food units required by the calf and the foods to supply them, on the assumption that it is to increase about 2½ pounds a day, from the third to the twenty-second week. The figures given are as for the last day of the week. Those for the other days may be found by subtracting from these figures those for the previous week and adding to the latter, according to the day of the week, $\frac{1}{7}$ . . . $\frac{6}{7}$ of the difference. The weeks may be divided into larger parts than sevenths, but, though labour may be lessened, the result may be scarcely as good. The figures in the column for hay must be taken as an *ad libitum* allowance. In every full mixed ration, one of the ingredients must be allowed to vary with the appetite of the animal. It may be that calves can be weaned sooner and fed more cheaply and yet make two and a half pounds a day. It may also be that they can be fed to make a still greater increase. On such questions, however, we can, as yet, only speculate and wait for evidence from well-devised experiments or enterprising experience.

The calf is now weaned, and, being over five months old, may go to pasture or upon a mixed ration. If his ration is a highly efficient one, the food required is indicated on on page 119.

If we have been on somewhat uncertain ground in dealing with the fattening of cattle, we are on ground which is still more uncertain in dealing with the fattening of sheep. Sheep-owners have been quicker than cattle owners to abandon long-continued "storing," and the three-year-old, even the two-year-old wedders, of former times are nowadays seldom n ; yet we have no definite knowledge either of the possible e of increase in fattening sheep of any size or of the most cient rations. Like those in fattening cattle, British ep-fattening experiments have followed no definite purpose l, so, have achieved no definite result which might become base for further advance. Moreover, sheep experiments liable to causes of variation upon which the experimenters ve seldom or never reported from which cattle feeding periments are almost entirely free. Cattle, being fed under

end of	Food units	Whole milk	Separated milk	Linseed	Indian meal	Crushed oats	Linseed Cake	Roots (as Mangels)	Hay
week		quarts	quarts	ozs.	lbs.	lbs.	lbs.	lbs.	lbs.
3rd	7.4	8	—	7	—	—	—	—	—
4th	7.6	7	1	8	½	—	—	—	½
5th	7.8	6	2	8	1	—	—	—	½
6th	8.0	5	3	8	1	½	—	—	½
7th	8.2	4	4	8	1	1	—	—	1
8th	8.4	3	5	4	1	1	1	—	1
9th	8.6	2	6	—	1	1	1½	—	2
oth	8.8	1	7	—	1	1½	1½	—	2
1th	9.0	—	8	—	1	1½	1½	5	3
2th	9.2	—	8	—	1	1½	1½	5	4
3th	9.5	—	8	—	1	1½	1½	7½	4
4th	9.7	—	8	—	1	1½	1½	10	4
5th	9.9	—	8	—	1	1½	1½	10	4½
6th	10.1	—	7	—	1	1½	1½	15	4½
7th	10.3	—	6	—	1	1½	1½	20	4½
8th	10.5	—	5	—	1	1½	1½	25	5
9th	10.7	—	4	—	1	1½	1½	25	6
oth	10.9	—	3	—	1	1½	1½	30	7
1st	11.1	—	2	—	1	1½	1½	30	8
2nd	11.3	—	1	—	1	2	1½	30	8

ver, are maintained in temperatures and states of comfort ich are, in most cases, approximately alike, but sheep are posed to many variations in temperature, wind, shelter, nfall, soil moisture and firmness and sloppiness of footing. veral experimenters fed sheep both under cover and in e open, but one only, Dr. J. W. Paterson, made a clear nparison between the two conditions, by feeding the sheep der each with exactly the same rations. The result was clearly in favour of cover, but the impression conveyed by the remaining experiments—and, in the circumstances, it can be no more than an impression—as will be seen by the diagram to follow, is in favour of fattening in the open. Nor is it possible to say, in many cases, that the experimental sheep ate no other food than that mentioned in the rations. A bullock tied up in a stall can get nothing but that put before him, but a sheep may pick up some grass, when penned upon pasture, and turnip leaves, small unpulled turnips, and even weeds and hedgerow herbage, when penned upon turnip ground. Thus, the British sheep-feeding experiments must be considered less satisfactory than those with cattle. As they are, the main results are to be found expressed in the diagram on next page, which is again based upon a digest published by Mr. Ingle in the 1910 volume of the "Transactions of the Highland and Agricultural Society of Scotland." In this case, the rations and gains are expressed by the week, which is convenient, for the reason that a sheep consumes and gains in the week nearly the same as a bullock consumes and gains in a day. The dots surrounded by a circle indicate the experiments carried out under cover. As in the diagram of the cattle-feeding experiments, the averages for the different groups of weights are marked by crosses which are joined up by a dotted line running across the diagram. A continuous line is also drawn, as near as may be, through the rations which readily produce a weekly gain of two pounds, and upright lines are drawn from these points of 2 pounds weekly increase through the average of the rations for each group of weights. As with the cattle, the efficiency of each ration is measured by the distance of its dot from the upright lines. This method, though very useful, is not highly accurate in extreme cases—it is accurate for cases near but not for those far above or below the cross line—and, as there are far more extremes in this than in the cattle diagram, an extra column is added to the table on pages 131, 132, and 133, showing the rations in detail. This extra column shows how many food units were required by each ration to produce a pound of gain, and indicates more closely than the diagrammatic method the relative efficiencies of the rations. This method itself is not absolutely accurate, but it will have to do mean-


FOOD UNITS
30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5
Live Weights
Weekly Increase in Lbs.
160-179 lbs.
140-159 lbs.
120-139 lbs.
100-119 lbs.
80-99 lbs.
60-79 lbs.
1 lb.
2
3
Maintenance line
FOOD UNITS

time. If we knew how many units sheep require for maintenance, then, by subtracting this number from the total units in the rations and dividing by the weekly increases, we should compare still more accurately the efficiencies of the rations ; but the maintenance figures have not yet been clearly determined. Hansson suggests, on Kellner's work, that larger sheep need 1.2 units and smaller 1.3 per 100 pounds live weight, but these figures may be too high. On them as a basis, a maintenance line is indicated across the diagram, but one lot of sheep in the set weighing 120-139 pounds, made a gain of half a pound a week on fewer units than the maintenance line requires while several other lots made gains inconsistent with its position. Of course, as already suggested, these sheep experiments are not to be relied upon too far.

From these tables, it is obvious that sheep do well neither with roots alone nor without a very considerable supply. In the few instances in which it was used, straw does not show itself to be a very economic ingredient of a ration. If roots are withheld entirely, the ration must contain a large quantity of hay or concentrates, or both. As none of the rootless rations contained a very large quantity of concentrates and a small quantity of hay, nothing can be said as to the efficiency of such a ration, but several contained very large quantities of hay, and all such were highly inefficient.

" Seems " is a very unsatisfactory word, but it must be used in the few remaining inferences. It will be noticed that, though there is a general fall in the quantity of roots with the rising efficiency of the rations, this fall is by no means regular. Thus sheep appear to be better able than cattle to accommodate themselves to varying quantities. No doubt there is a limit to the quantity of roots a sheep may consume without the economy of the ration being depressed, but these experiments do not allow us to come closer than say that a sheep may consume with safety something more than its own weight of roots in a week, or a seventh of its own weight in a day.

The experiments also indicate that, if the ration contain the safe quantity of roots, the sheep is comparatively indifferent

LIVE WEIGHT OF ANIMALS.

60–79 lbs.

No.	Food units consumed per week	Weekly gains	WEEKLY RATIONS				Diagrammatic efficiency	Food units required to produce a pound of gain
			Straw	Hay	Roots	Concentrates		
		lbs.	lbs.	lbs.	lbs.	lbs.		
1	10.30	.54	—	—	126.5	—	— 14	19.1
2	9.97	.64	3.14	3.14	43.70	3.5	— 12	15.6
3	20.69	1.61	—	3.36	99.75	6.82	— 17	12.5
4	16.14	1.26	—	5.6	91.	3.5	— 16	12.8
5	17.05	1.36	—	3.21	82.6	6.58	— 17	12.5
6	17.45	1.41	—	—	122.	3.5	— 16	12.4
7	10.75	.90	—	1.65	63.6	4.5	— 11	11.9
8	13.84	1.26	—	4.66	—	11.48	— 13	11.0
9	10.09	.94	—	1.65	63.6	4.5	— 10	10.7
10	13.84	1.33	—	4.66	—	11.48	— 12	10.4
11	16.74	1.77	—	—	124.4	3.5	— 12	9.5
12	12.30	1.34	—	5.6	91.	3.5	— 9	9.2
13	13.30	1.46	—	—	119.6	—	— 10	9.1
14	10.74	1.20	—	1.20	63.6	4.5	— 8	8.9
15	10.74	1.34	—	1.65	63.6	4.5	— 7	8.
16	10.09	1.28	—	1.65	63.6	4.5	— 7	7.9
17	9.29	1.17	—	4.2	68.5	—	— 6	7.9
18	10.80	1.42	—	4.6	81.	—	— 6	7.6
19	16.02	2.22	—	—	111.	3.5	— 6	7.2
20	9.05	1.29	—	4.25	67.1	—	— 5	7.0
21	10.72	1.56	—	1.65	63.6	4.5	— 5	6.9
22	9.51	1.46	—	4.35	70.9	—	— 4	6.5
80–99 lbs.								
23	13.81	.97	—	—	84.9	5.25	— 13	14.2
24	17.64	1.42	—	—	99.1	6.3	— 14	12.4
25	21.52	1.85	—	3.63	117.	7.07	— 16	11.6
26	11.45	1.19	—	—	103.1	—	— 7	9.6
27	13.33	1.47	—	4.76	102.9	—	— 7	9.0
28	17.26	2.42	—	—	126.8	3.51	— 4	7.1
29	14.87	2.15	—	—	96.1	3.77	— 3	6.9
30	15.80	2.32	—	3.64	80.5	5.14	— 2	6.8
31	15.66	2.42	—	3.29	98.7	5.14	— 2	6.6
32	17.73	2.79	—	—	126.8	3.5	— 1	6.3
33	15.66	2.49	—	—	89.6	5.14	— 1	6.3
34	16.14	2.56	—	3.5	90.3	5.14	— 1	6.3
35	16.10	2.54	—	3.57	90.3	5.14	— 1	6.3
100–119 lbs.								
36	16.87	1.36	—	5.25	70.	6.42	— 12	12.4
37	18.82	1.63	—	—	103.6	7.81	— 12	11.5
38	13.22	1.17	—	—	82.6	7.00	— 8	11.3
39	20.41	2.00	—	—	126.8	8.25	— 11	11.2
40	16.29	1.47	—	5.25	70.	6.42	— 10	11.1
41	13.03	1.35	—	—	82.6	7.00	— 6	9.6
42	15.84	1.71	—	—	103.2	4.83	— 7	9.3

LIVE WEIGHT OF ANIMALS—*continued.*

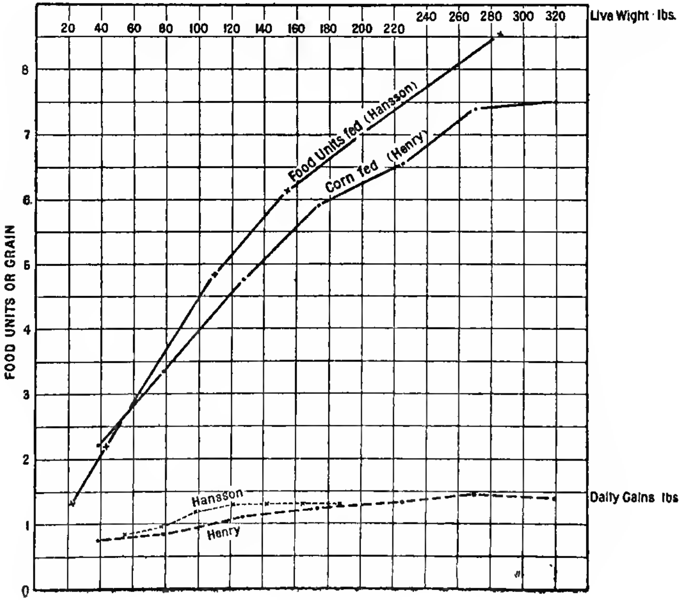
No.	Food units consumed per week	Weekly gains	WEEKLY RATIONS				Diagrammatic efficiency	Food units required to produce a pound of gain
			Straw	Hay	Roots	Concentrates		
100–119 lbs.								
		lbs.	lbs.	lbs.	lbs.	lbs.		
43	23.20	2.55	—	—	141.	6.78	— 10	9.1
44	18.30	2.03	—	5.88	79.06	6.19	— 8	9
45	17.43	1.93	—	—	107.5	7.14	— 7	9
46	20.62	2.29	—	4.23	141.0	3.36	— 8	9
47	22.06	2.57	—	4.23	141.0	4.26	— 8	8.6
48	21.95	2.56	—	—	126.8	8.57	— 8	8.5
49	19.17	2.28	—	2.36	132.3	3.64	— 6	8.4
50	17.28	2.09	—	4.80	87.83	4.81	— 6	8.3
51	18.27	2.22	—	5.6	82.8	5.88	— 6	8.2
52	17.29	2.12	—	5.31	78.	5.60	— 5	8.1
53	10.33	1.33	—	3.38	80.8	—	— 2	7.8
54	15.98	2.07	—	1.96	99.2	5.83	— 4	7.7
55	15.90	2.18	—	2.02	95.5	5.83	— 2	7.3
56	15.07	2.06	—	—	105.	6.54	— 2	7.3
57	14.48	2.00	—	1.55	84.3	5.80	— 2	7.2
58	17.29	2.39	—	4.81	88.	4.81	— 3	7.2
59	17.10	2.36	—	2.62	96.	5.83	— 2	7.2
60	14.76	2.06	—	3.3	121.	—	— 2	7.1
61	18.08	2.54	—	2.91	94.8	5.75	— 2	7.1
62	14.04	2.06	—	—	105.	5.94	0	6.9
63	18.84	2.76	—	3.03	117.	4.76	— 1	6.8
64	14.19	2.16	—	3.12	83.6	5.88	0	6.6
65	15.12	2.32	—	2.24	86.3	4.6	0	6.5
66	17.52	2.71	—	2.67	114.2	4.86	0	6.4
67	17.22	2.73	—	2.8	118.	4.21	+ 1	6.3
68	14.41	2.32	—	2.5	87.5	5.20	+ 1	6.2
69	14.71	2.39	—	1.68	92.8	5.02	+ 1	6.1
70	16.60	2.86	—	3.29	82.1	5.55	+ 3	5.8
71	14.56	2.54	—	1.70	91.5	5.20	+ 3	5.7
72	14.95	2.60	—	—	88.9	7.94	+ 3	5.7
73	13.58	2.38	—	—	105.	4.66	+ 2	5.7
74	14.58	2.80	—	—	105.	8.04	+ 5	5.2
120–139 lbs.								
75	14.10	.99	—	18.56	—	6.7	— 9	14.3
76	14.25	1.02	—	18.13	—	7.0	— 9	14.
77	20.76	1.51	—	20.	—	7.	— 14	13.7
78	9.15	.53	—	22.83	—	—	— 5	13.5
79	17.66	1.39	—	3.5	98.	4.81	— 11	12.7
80	17.66	1.43	—	3.5	98.	4.81	— 10	12.4
81	18.37	1.61	—	22.13	—	7.	— 9	11.4
82	16.5	1.46	—	20.88	—	7.	— 8	11.3
83	24.40	2.16	—	3.10	165.5	4.30	— 14	11.3
84	16.89	1.58	—	10.5	80.5	8.75	— 8	10.7
85	20.64	1.97	—	1.97	121.2	5.62	— 9	10.5
86	17.5	1.67	—	10.5	80.5	5.83	— 8	10.5
87	17.66	1.73	—	3.5	98.	4.81	— 7	10.2

LIVE WEIGHT OF ANIMALS—*continued.*

No.	Food units consumed per week	Weekly gains	WEEKLY RATIONS				Diagrammatic efficiency	Food units required to produce a pound of gain
			Straw	Hay	Roots	Concentrates		
120–139 lbs.								
		lbs.	lbs.	lbs.	lbs.	lbs.		
88	13.49	1.34	·5	—	120.25	—	— 4	10
89	22.25	2.45	—	—	160.4	4.20	— 7	9.9
90	17.01	1.76	—	5.25	70.	6.42	— 6	9.7
91	17.12	1.83	—	10.5	80.5	5.83	— 5	9.4
92	16.65	2.00	—	—	96.5	7.	— 3	8.3
93	18.41	2.23	—	5.66	83.8	5.88	— 3	8.3
94	23.60	2.87	—	—	147.28	6.86	— 5	8.2
95	23.05	2.92	—	2.03	160.3	4.2	— 4	7.9
96	19.04	2.41	1.56	1.56	93.1	7.28	— 2	7.9
97	21.84	2.76	—	2.3	140.	4.7	— 4	7.9
98	13.40	1.71	1.94	14.5	—	5.06	0	7.8
99	20.80	2.69	—	2.3	140.	4.7	— 2	7.7
100	20.80	2.71	—	2.3	140.	4.7	— 1	7.7
101	16.64	2.21	—	8.25	116.	—	— 1	7.5
102	17.19	2.45	—	—	89.75	6.5	+ 1	7
103	16.23	2.35	—	—	82.25	8.5	+ 1	7
104	19.93	2.85	—	2.56	125.1	4.96	0	7
105	19.56	2.79	—	2.44	126.0	4.87	0	7
106	19.88	2.90	—	3.87	112.5	5.25	+ 1	6.8
107	20.85	3.15	—	—	147.28	6.86	+ 2	6.6
108	19.55	3.	—	2.43	126.1	4.84	+ 2	6.5
109	18.86	2.93	—	3.22	121.6	3.65	+ 3	6.4
110	19.21	3.06	1.58	1.58	93.1	7.48	+ 3	6.3
111	21.17	3.46	—	2.3	140.	4.7	+ 4	6.1
112	20.66	3.47	—	2.68	117.1	4.71	+ 5	5.9
113	13.42	2.3	—	—	82.6	7.	+ 5	5.8
114	15.91	2.73	—	1.72	104.	4.99	+ 6	5.8
115	21.30	3.71	—	2.66	134.12	5.11	+ 6	5.7
116	15.60	2.82	—	3.79	72.53	4.93	+ 7	5.5
117	12.44	2.39	—	—	82.6	5.25	+ 8	5.2
140–159 lbs.								
118	22.22	2.68	—	7.	106.6	8.	— 3	8.3
119	25.00	3.02	1.30	1.30	174.5	4.34	— 4	8.3
120	25.99	3.20	—	—	171.6	7.07	— 4	8.1
121	24.75	3.18	—	6.88	113.25	8.06	— 2	7.7
122	19.57	2.54	—	3.04	118.8	4.79	0	7.7
123	18.75	2.53	—	—	117.5	7.	1	7.4
124	21.69	3.38	—	2.3	140.	4.7	6	6.4
160–179 lbs.								
125	27.50	2.18	—	3.5	185	5.26	— 14	12.6
126	27.27	2.29	—	3.5	194.6	5.25	— 12	11.9
127	27.65	2.38	—	3.5	184.8	5.26	— 12	11.6
128	29.38	2.78	—	3.5	196	5.25	— 11	10.6
129	29.63	3.16	—	3.5	201.6	5.25	— 8	9.4

as to whether the rest of it is made up of hay or concentrates or both. Thus, all that may be suggested in the meantime is that a sheep should have something more than a seventh of its own weight of roots in the day, a half to three-quarters of a pound of concentrates, and as much hay as it cares to eat.

Many pigs are fed, and well fed, in the dairying districts of Britain and Ireland, but, for evidence as to how they should be fed, we have to appeal to Scandinavia and America, where many systematic experiments have been carried out. Luckily, as the pig's food consists almost entirely of concentrates, he has little chance of being offered such inefficient rations as are frequently offered to cattle and sheep. Thus, the chief thing to be known is the quantity of food to be offered him at different stages of growth. This is to be found in the following diagram which gives the recommendations of Professor Henry, whom we shall take as representing America,



and Professor Nils Hansson as representing Scandinavia. The upper lines show how much food is to be given as the pig increases in weight—Hansson's recommendations are given in food units, i.e., barley, and Henry's in pounds of "corn," i.e. maize—and the lower lines the daily gains which have been made on the recommended quantities.

Two other points only need be mentioned, namely, that, as he grows with extraordinary rapidity, for his size, the young pig should have in his food a comparatively large supply of albuminoids and salts, and, as the maintenance portion of his ration becomes unusually large, as he increases in size—about two food units produce a pound of gain when he is half a hundredweight, but four are required before he is two hundredweights—the fattening should not be unduly prolonged. To promote growth of muscle and bone, it is doubtful whether anything, except the mother's milk, is better than separated milk, and, if the mother be a poor milker, this may be added to the suckling pig when it is three or four weeks old. At five or six weeks, a small quantity of boiled potatoes and oat or wheat meal may be mixed with the separated milk. The pig does well at no time, but especially when very young, with fibrous foods. Henry found that the suckling pig may be "fed through the mother" at the same cost as feeding it directly, but this cannot be done unless the mother be well endowed for milk production. Otherwise she can only grow fat.

The weaned pig weighs from 35 to 40 pounds, and requires about 2 food units. These can be made up, one from separated milk (6 pounds), the other from potatoes and meal: say 2 pounds of potatoes, boiled (½ unit), and ½ pound of barley or maize meal (½ unit). As the pig grows heavier, his ration should be increased, according to the diagram, but at no stage should the weight of milk be more than about three times greater than that of the solids, and, when he is well grown, say at 120 to 140 pounds live weight, the milk should be gradually diminished and fattening finally completed upon potatoes and meals. Nothing need be cooked but potatoes, but all solids should be made into a porridge or, at least, well moistened. This presumes that the pig is to be fattened off at what is not far beyond the optimum weight, about two hundredweights, and that no table or other refuse is procurable. The following rations might be suggested as samples at different weights :

	At 60 pounds	At 120 pounds	At 180 pounds
	lbs. units	lbs. units.	lbs. units
Separated milk	10 = 1.33	15 = 2.5	6 = 1.
Potatoes	4 = 1	6 = 1.5	8 = 2.
Maize meal	.5 = .47	1 = 1.1	2 = 2.2
Barley meal			.5 = .5
	2.8	5.1	6.7

CHAPTER IX

THE APPROXIMATE MONEY VALUE OF FEEDING STUFFS

IT has been customary, for some time, to value manures by what has been called the unit system. In this system, a unit is one per cent of a ton, i.e. 22.4 pounds, and a ton of manure which contains, say, twenty per cent of any manurial substance is said to contain twenty units of that substance. The money value of a unit is found by dividing the price per ton by the number of units it contains. If sulphate of ammonia contain twenty per cent of nitrogen and sell at £15 a ton, the value of a unit of nitrogen is 15/– ($\frac{300}{20}$). Similarly, if a ton of superphosphate, containing thirty per cent of soluble phosphate, sell at £3 a ton, the value of a unit of soluble phosphate is 2/– ($\frac{60}{30}$) ; and, if a ton of kainit, containing twelve per cent of potash, sell at £2 14s., the value of a unit of potash is 4/6 ($\frac{54}{12}$). These unit prices are then used to find the value of a ton of any manure containing one, two or all three manurial ingredients. For instance, if a ton of manure contain five per cent of nitrogen, eight per cent of potash, and twenty per cent of soluble phosphate, its value is :

	£	s.	d.
5 units of nitrogen at 15/–	3	15	0
8 units of potash at 4/6	1	16	0
20 units of soluble phosphate at 2/–	2	0	0
	7	11	0

The prices paid for them are no indication of the utility of these manurial ingredients—22.4 pounds of nitrogen are not necessarily seven and a half times as useful as 22.4 pounds of soluble phosphate—but rather indications of the difficulties in finding supplies to meet the demands. If nitrogen were more easily found or less were demanded, its price would come down.

The same method may be used to find the approximate money values of food stuffs, but the calculations are much less simple. The manures from which the unit values are derived contain each only one manurial ingredient, and the calculation is merely one of simple division ; but feeding stuffs usually contain all three nutritive ingredients—albuminoids, fats, and carbohydrates—and the unit values are not got by simple division but by more complicated methods. As, in a manure, only the ingredients having manurial utility, so, in feeding stuffs, only the ingredients having nutritive utility are valued. And, as in manures, the unit values found for them do not indicate the true nutritive utilities of the different ingredients, but rather the values brought about by the supplies being only more or less equal to the demands. Till thirty or forty years ago, farmers were inclined to look upon fat as the most important constituent in a food, but, as the notions which were chiefly responsible for the albuminoid ratio theory found wider acceptance, albuminoids came more and more into prominence ; and, since they are still highly regarded not only as a nutrient but as having manurial value, while, for their own purpose, they cannot be replaced, and their supply is relatively small, we should expect their money value to be considerably higher than that of the more widely produced carbohydrates, perhaps even than that of fat. We should also expect fats to be at least 2.3 times as valuable as carbohydrates.

In choosing a manure, preference is given to those which are more highly concentrated, because, in their case, transport and handling cost less, and the soil is expected easily to sift the useful from the useless. In choosing feeding stuffs, the preference for the concentrated is much greater, partly because of ease in transport and handling, but chiefly because, with a like expenditure of energy, stock can extract far more nutriment from concentrated than from highly indigestible foods. Stock are given but little time and must work to have the useful separated from the useless ; and, in some cases, the labour expended may not be balanced by the nutriment extracted. Zuntz's horse died of starvation though fed with as much wheat straw as he cared to eat.

Just as there are a few manures which are obtained and used in large quantity and, for these reasons, remain fairly constant in price, so there are a few grains and one bye-product, namely beans, peas, maize, and wheat bran, which are widely grown, almost universally used for stock-feeding, and remain fairly constant in price. The unit values of digestible albuminoids, fats and carbohydrates may be calculated from these. Oats, barley, wheat, and rice are grown in great quantity but are largely used for human food, and the prices paid for them are generally higher than they would be if they were used chiefly for stock feeding. For that reason, they cannot be used in calculating the values of feeding stuffs. Nor can artificially manufactured cakes be safely used, chiefly because they are irregular in composition, but also because the older kinds are usually over-appreciated while the newer kinds are under-appreciated.

The following table gives the percentages of digestible fats, albuminoids, and carbohydrates in maize, beans, peas, and wheat bran, and the prices per ton at which the foods themselves were selling in Glasgow market during the winter of 1912–13. The percentages, which are taken from Nils Hansson's "Utfodringslära," published in 1916, are in close agreement with those formerly published by Kellner and other authorities. "Digestible albuminoids" mean all digestible albumens and other nitrogenous substances, and "digestible carbohydrates" all digestible starch, fibre, and allied substances. The prices of the foods are taken from the weekly reports in "The Scottish Farmer" during the latter half of the winter 1912–13. Prices had risen for a year or two before this, and were then near their maximum till the war made them abnormal. Later prices have not been taken, because, when equilibrium returns, the prices then holding are much more likely to be parallel, though not necessarily equal, with those before than with those at any time during, or immediately after, the war. In any case, with the figures we shall work out, it will always be possible, by finding how much the standard food stuffs have risen, to calculate the approximate money value of any other food.

	Digestible fats	Digestible albuminoids	Digestible carbohydrates	Price per ton
Maize	4.2	7.2	65.3	120/-
Beans	1.2	22.1	48.2	145/-
Peas	.9	20.2	51.3	141/-
Bran	3.1	12.6	44.1	110/-

From this table, three equations can be found from which the unit values of digestible fats, albuminoids, and carbohydrates may be calculated with sufficient accuracy for all ordinary purposes, by Gauss's method, thus :

$$\begin{array}{llrcrcrcrcr}
\text{From Maize multiplied by} & 4.2 & : & 17.64\,F & + & 30.24\,A & + & 274.26\,C & = & 504 \\
\text{,, Beans ,,} & 1.2 & : & 1.44\,F & + & 26.52\,A & + & 57.84\,C & = & 174 \\
\text{,, Peas ,,} & .9 & : & .81\,F & + & 18.18\,A & + & 46.17\,C & = & 126.9 \\
\text{,, Bran ,,} & 3.1 & : & 9.61\,F & + & 39.06\,A & + & 136.71\,C & = & 341 \\
\hline
(1) & & & 29.50\,F & + & 114.00\,A & + & 514.98\,C & = & 1145.9
\end{array}$$

$$\begin{array}{llrcrcrcrcr}
\text{From Maize multiplied by} & 7.2 & : & 30.24\,F & + & 51.84\,A & + & 470.16\,C & = & 864 \\
\text{,, Beans ,,} & 22.1 & : & 26.52\,F & + & 488.41\,A & + & 1065.22\,C & = & 3204.5 \\
\text{,, Peas ,,} & 20.2 & : & 18.18\,F & + & 408.04\,A & + & 1036.26\,C & = & 2848.2 \\
\text{,, Bran ,,} & 12.6 & : & 39.06\,F & + & 158.76\,A & + & 555.66\,C & = & 1386 \\
\hline
(2) & & & 114.00\,F & + & 1107.05\,A & + & 3127.30\,C & = & 8302.7
\end{array}$$

$$\begin{array}{llrcrcrcrcr}
\text{From Maize multiplied by} & 65.3 & : & 274.26\,F & + & 470.16\,A & + & 4264.49\,C & = & 7836 \\
\text{,, Beans ,,} & 48.2 & : & 57.84\,F & + & 1065.22\,A & + & 2323.24\,C & = & 6989 \\
\text{,, Peas ,,} & 51.3 & : & 46.17\,F & + & 1036.26\,A & + & 2631.69\,C & = & 7233.3 \\
\text{,, Bran ,,} & 44.1 & : & 136.71\,F & + & 555.66\,A & + & 1944.81\,C & = & 4851 \\
\hline
(3) & & & 514.98\,F & + & 3127.3\,A & + & 11164.23\,C & = & 26909.3
\end{array}$$

$$\text{From (1)* } F = \frac{1146 - 114\,A - 515\,C}{29.5}$$

By substituting this value of F in (2), we get

$$1107\,A + 3127C = 8303 - 114\,\frac{(1146 - 114A - 515C)}{29.5}$$

$$\therefore 29.5 \times 1107A - 114 \times 114A + 29.5 \times 3127C - 114 \times 515C = 29.5 \times 8303 - 114 \times 1146$$

$$\therefore 32657A - 12996A + 92247C - 58710C = 244939 - 130644$$

$$(4) \therefore 19661A + 33537C = 114295$$

Substituting the same value of F in (3), we get

$$3127A + 11164C = 26909 - 515\,\frac{(1146 - 114A - 515C)}{29.5}$$

$$\therefore 29.5 \times 3127A - 515 \times 114A + 29.5 \times 11164C - 515 \times 515C = 29.5 \times 26909 - 515 \times 1146$$

$$\therefore 92247A - 58710A + 329338C - 265225C = 793816 - 590190$$

$$(5) \therefore 33537A + 64113C = 203626$$

Multiplying (4) by 1.706, we get

$$(6) \quad 33537A + 57214\,C = 194987$$

Subtracting (6) from (5) we get

$$6899\,C = 8639$$

$$(7) \quad \therefore C = 1.252$$

---

* The final result is practically the same whether the value of F he got from (1), (2), or (3).

Substituting 1.252 for C in (4) and (5),

we get $19661\,A = 114295 - 1.252 \times 33537$
and $33537\,A = 203626 - 1.252 \times 64113$

(8) By either equation $A = 3.678$

Finally, substituting 3.678 for A and 1.252 for C in (1), we get

$$F = \frac{1146 - 3.678 \times 114 - 1.252 \times 515}{29.5}$$

$$= \frac{1146 - 419.292 - 644.78}{29.5}$$

$$= \frac{81.928}{29.5}$$

$$\therefore\ F = 2.777$$

The accuracy of these results may be tested by applying them to the foods from which they have been derived, thus :

	Calculated value in shillings	Market price, shillings
Maize		
4.2 digestible fat × 2.777 = 11.6639		
7.2 ,, albuminoids × 3.678 = 26.4816		
65.3 ,, carbohydrates × 1.252 = 81.7556		
	119.9011	120
Beans		
1.2 digestible fat × 2.777 = 3.3324		
22.1 ,, albuminoids × 3.678 = 81.2838		
48.2 ,, carbohydrates × 1.252 = 60.3464		
	144.9626	145
Peas		
.9 digestible fat × 2.777 = 2.4993		
20.2 ,, albuminoids × 3.678 = 74.2956		
51.3 ,, carbohydrates × 1.252 = 64.2276		
	141.0225	140
Bran		
3.1 digestible fat × 2.777 = 8.6087		
12.6 ,, albuminoids × 3.678 = 46.3428		
44.1 ,, carbohydrates × 1.252 = 55.2132		
	110.1647	110

But sellers of feeding stuffs and farmers do not calculate by figures which are extended to three decimal places. Thus, 2.777, 3.678, and 1.252 shillings may be turned into simple shillings and pence, and the unit values, as determined by the prices of maize, beans, peas, and bran in the winter of 1912–13, become :

Digestible fats	2/9
,, albuminoids	3/8
,, carbohydrates	1/3

These figures may now be used to indicate the approximate money value of a ton of any other concentrated feeding stuff, as, for instance :

Linseed Cake.

		£	s.	d.
25.8 digestible albuminoids at	3/8	4	14	6
8.7 ,, fats at	2/9	1	3	10
31.8 ,, carbohydrates at	1/3	1	19	9
		7	18	1

Decorticated Cotton Cake.

37.3 digestible albuminoids at	3/8	6	16	9
9.2 ,, fats at	2/9	1	5	4
18.3 ,, carbohydrates at	1/3	1	2	11
		9	5	0

Earthnut cake.

41 digestible albuminoids at	3/8	7	10	4
7.2 ,, fats at	2/9	0	19	10
21.9 ,, carbohydrates at	1/3	1	7	4
		9	17	6

It may be well to say again that these figures do not represent the nutritive values of these three cakes—their nutritive values are better found by using the Scandinavian food units—but their money values as determined by the supplies and demands for digestible albuminoids, fats and carbohydrates. Albuminoids were erroneously appreciated and far too much was paid for them ; and, now that we understand their nutritive value better than we did, it is to be expected that demand and supply will bring their money and their nutritive values closer together.

These unit values are, perhaps, best employed in determining the approximate money values of mixed cakes, that is, cakes manufactured from two or more substances. Many such cakes are produced and are frequently sold beyond their value. Since Parliament decided, some years ago, that only albuminoids and fats need be guaranteed, sellers have generally omitted to state the proportions of carbohydrates in cakes and meals. The omission can be filled in, however, with approximate accuracy. In the original substances, and therefore in manufactured cakes and meals, there are five constituents, namely, albuminoids, fats, carbohydrates, ash, and water. Since the percentages of the two first are stated, and, since the balance must be made up of the remaining three, the percentage of carbohydrates can be estimated, if those for ash and water be known. Ash, in grain and cakes, usually varies between two and seven per cent, but, since the substances used to produce mixed cakes generally contain a high proportion, the average quantity of ash in such cakes and meals may be set down at six or seven per cent. Water is generally about 11 to 13 per cent. Thus, if a cake or meal be guaranteed to contain twenty per cent of albuminoids and five of fat, the percentage of carbohydrates in it is approximately a hundred less twenty of albuminoids, five of fat, six of ash, and thirteen of water : that is, fifty-six.

But what proportions of the albuminoids, fats, and carbohydrates are likely to be digestible ? The average percentages—usually called the "digestion coefficients"—in some grains and their bye-products—the figures for fibre being given separately—are as follows :

	Albuminoids	Fats	Carbohydrates	Fibre
Barley	75	89	92	35
Oats	80	83	77	25
Maize	72	89	95	58
Beans	87	80	91	58
Peas	86	65	93	46
Linseed	80	95	80	33
Buckwheat	75	73	77	24
Wheat bran	83	77	75	26
Barley " bran "	65	89	86	35
Dried grains	71	88	60	48
Malt combs	80	73	73	55
Oat husks	—	40	36	33
Dried yeast	90	75	95	55
Undecorticated cotton cake	74	94	55	25
Cocoa hulls	20	84	48	21
Pea bran	75	71	92	80

From this table, which refers to some of the things which go to make mixed cakes and meals, it is obvious that no digestion coefficients can be used with certainty, so long as the initial ingredients and their relative proportions are unknown. It is also obvious that certain ingredients and others of a similar nature may seriously lower the digestibility of a cake or meal of which they form a part. All that can be done, therefore, is to suggest digestion coefficients for the better cakes and meals and say they must be reduced in others according to the kind and quality of fibre they contain. The figures are 75 to 80 for albuminoids, 80 to 85 for fat, and 65 to 70 for carbohydrates and fibre together. On that basis, at its best, the approximate money value of a cake guaranteed to contain twenty per cent of albuminoids and five per cent of fat works out as follows :

	Total	Digestion coefficient	Digestible	Approximate value		
				£	s.	d.
Albuminoids	20%	80	16 %	2	18	8
Fat	5%	85	4.25%		11	8
Carbohydrates	56%	70	39.2 %	2	9	0
				£5	19	4

Since they are almost invariably sold in restricted markets, it is impossible to set down general prices for roots and long fodders. Thus, from themselves as a basis, the unit values of their useful constituents cannot be calculated. Since, however, they do not suffer from the presence of large quantities of fibre and are as digestible as concentrates, presumably the approximate money values of roots should be found on the same basis as that for concentrates. If this assumption be wrong, it is not far wrong, and it will be at least interesting to know, with some presumption of approximate accuracy, how much ought to be paid for a ton of several kinds of roots. In roots, however, the proportion of immature albuminoids—amides—is too large to have the "digestible albuminoids" valued at the same figure as in concentrates. Amides are less nutritive than carbohydrates, but they have some manurial value. Thus we shall put their value at that of carbohydrates and the true albumens at that of albuminoids in concentrates. Then, the approximate money values for feeding purposes of a ton of swedes, mangels, turnips, and carrots and pototoes are as follows:

Swedes:	Units			£	s.	d.
Digestible albuminoids	.5	at	3/8	0	1	10
,, fats	.1	,,	2/9	0	0	3
,, amides	.5	,,	1/3	0	0	8
,, carbohydrates	8.9	,,	1/3	0	10	11
				0	13	8

Mangels:						
Digestible albuminoids	.4	,,	3/8	0	1	6
,, fats	.1	,,	2/9	0	0	3
,, amides	.6	,,	1/3	0	0	9
,, carbohydrates	8.1	,,	1/3	0	10	1
				0	12	7

	Units			£	s.	d.
Turnips:						
Digestible albuminoids	.4	at	3/8	0	1	6
,, fats	.1	,,	2/9	0	0	3
,, amides	.5	,,	1/3	0	0	8
,, carbohydrates	6.1	,,	1/3	0	7	7
				0	10	0
Carrots:						
Digestible albuminoids	.5	,,	3/8	0	1	10
,, fats	.1	,,	2/9	0	0	3
,, amides	.4	,,	1/3	0	0	6
,, carbohydrates	9.6	,,	1/3	0	12	0
				0	14	7
Potatoes:						
Digestible albuminoids	.4	,,	3/8	0	1	6
,, fats	—	,,	—		—	
,, amides	.7	,,	1/3	0	0	9
,, carbohydrates	18.9	,,	1/3	1	3	7
				1	5	10

These and the previous examples as to cakes will indicate how, with the digested percentages, as given in the following table, the approximate money values of the common cakes, meals, and roots may be worked out.

The food units, which are also given in the following table, may be used to find the approximate utility value, as expressed in money, of the common food stuffs, apart from all considerations of markets, manurial residues, and long-established prejudices: that is, the animal's valuation of its food. If a ton of feeding barley cost 110/–,[1] and it take ten tons of mangels to provide as much nutriment as is provided by a ton of barley, then the approximate utility value of a ton of mangels is 110/- ÷ 10, that is 11/-. The utility value of any food is found by dividing its equivalent as compared with barley into the price of barley. The following are a few examples :

---

[1] If the price of feeding barley be not known, it can be found from that of maize, which is perhaps the steadiest in price of all foods, by multiplying the price of maize by .95 and dividing the result by 1. Thus 117 × .95 = 111.6 shillings.

Oats	110/- ÷ 1.2 = 91/8
Potatoes	110/- ÷ 4 = 27/6
Meadow hay	110/- ÷ 2.5 = 44/-
Medium oat straw	110/- ÷ 4 = 27/6
Green Italian rye grass	110/- ÷ 6 = 18/4
Dried grains	110/- ÷ 1.3 = 84/7
Linseed cake (9.5 % oil)	110/- ÷ .9 = 122/3
Decorticated cotton cake (9.8 % oil)	110/- ÷ .85 = 129/5
Earthnut cake (8 % oil)	110/- ÷ .8 = 137/6
Linseed	110/- ÷ .6 = 183/8

TABLE SHOWING THE AVERAGE PERCENTAGE COMPOSITION OF FOODSTUFFS WITH THE PERCENTAGE WHICH IS DIGESTIBLE, AND THE NUMBER OF POUNDS OF EACH FOOD NECESSARY TO MAKE A FOOD UNIT.

		TOTAL				DIGESTIBLE					POUNDS TO A FOOD UNIT.	
	Dry Matter	Albuminoids	Fats	Carbo-hydrates	Fibre	Albuminoids	Amides	Fat	Carbo-hydrates	Fibre	Variation	Average
	%	%	%	%	%	%	%	%	%	%		
Wheat	86.6	12.5	1.9	68.6	1.9	9.3	1.2	1.2	63.1	.9	.95-1.1	1
Rye	86.6	12.	1.7	69	1.9	9.1	1.	1.1	63.5	1	.95-1.1	1
Barley	85.5	10.	1.9	67.1	4.0	6.5	1.	1.7	61.7	1.4	.95-1.1	1
Oats	86.2	10.9	4.8	58.1	9.3	7.7	1.	4.	44.7	2.3	1.1 -1.3	1.2
Maize	86.2	10.	4.7	67.1	2.7	6.5	.7	4.2	63.7	1.6	.9 -1	.95
Peas	85.6	23.5	1.4	52.5	5.4	17.2	3	.9	48.8	2.5	.95-1.1	1
Beans	85.7	25.4	1.5	48.5	7.1	19.3	2.8	1.2	44.1	4.1	.95-1.1	1
Linseed	92.9	24.2	36.5	22.9	5.5	18.1	1.3	34.7	18.3	1.8		.6
Hempseed	91.1	18.2	32.6	21.1	15.	12.8	.9	29.3	14.1	3.8		.7
Rapeseed	92.7	19.6	45.	18.	5.9	13.8	2.1	42.8	14.4	1.5		.55
Wheat Bran	88.2	15.2	4	56	8	10.8	1.8	3.1	42.0	2.1	1.1 -1.3	1.2
Barley Bran	87.7	10.3	4.7	54.9	12.2	5.8	.9	4.2	47.2	4.3	1.1 -1.5	1.2
Oat Shells	86	1.9	.5	45.8	32.4	—	—	.2	16.5	10.7	3.5 -4.5	4
Pea Skins	88.3	16.8	1.7	46.2	20.1	11.3	1.3	1.2	42.5	16.1	1 -1.3	1.1
Barley Meal	86.8	12.6	2.9	65.4	3.0	9.2	.5	2.3	60.2	.7	1 -1.2	1
Rice Meal	87.4	12.	12.	45.2	8	6.0	.8	10.2	36.2	2.	1.1 -1.2	1.1
Gluten-feed (English)	90.5	24	2.5	54.9	6.8	19.4	1.5	2.3	45	3.7	.9 -1	.95
Gluten Feed (American)	90.5	26.3	3.2	50.8	6.3	17.5	5.4	2.9	41.7	3.4	.9 -1	.95
Malt Combs	88	23.1	1.5	45.3	12.3	11.4	7.1	1.1	33.1	6.8	1.2 -1.4	1.3
Dried Yeast	88	50.9	3.2	27.2	.4	42.	3.8	2.4	25.8	.2	.8 - .9	.8
Earthnut Cake	90	45.5	8	25.2	4.8	39.6	1.4	7.2	21.2	.7	.75- .9	.8
Sesame Cake	91	37.	12	23.7	7.8	32.4	1.6	11.3	16.8	5.7	.75- .9	.8
Soya Cake	88	43.3	5.5	28.7	5.	37.8	1.2	4.8	27	4.	.8 - .9	.8
Soya Meal	88	45.5	1.9	29.9	5.	40.1	1.8	1.7	28.4	4	.8 - .9	.85
Decorticated Cotton Cake	91	43.4	9.8	24.2	7.6	35.9	1.4	9.2	16.2	2.1	.8 - .9	.85
Undecorticated Cotton Cake	90	24.	6.5	28.3	25.	16.8	1	6.1	15.6	6.3	1.2 -1.6	1.4
Linseed Cke.	89	30	9.5	33.9	9.5	24.2	1.6	8.7	27.1	4.7	.8 -1	.9
Rape Cake	91	32	8.5	31.2	12.2	23.3	3.3	8.	25.	2.2	.9 -1	.95
Palm Cake	89	17	8	36.	24	12.5	.4	7.1	29.9	9.4	.9 -1.1	1
Palm Kernel Meal	89.1	18.7	1.6	39.1	25.4	15.4	.5	1.5	33.2	15.2	.9 -1.1	1
Cocoa Cake	89.5	21.4	8.5	38.7	14.7	16.3	.4	8.2	32.1	9.3	.85-1	.9
Flesh Meal	89.3	72.3	13.2	—	—	63.6	3.6	12.5	—	—	.6 - .7	.6
Fish Meal (Lean)	87.2	52.5	2.1	—	—	43.6	3.7	1.6	—	—	1 -1.2	1.1
Fish Meal (Fat)	89.2	48.4	11.6	—	—	40.1	3.5	11.0	—	—	.8 - 1	.9
Blood Meal	91.	83.9	2.5	—	—	76.	1.2	2	—	—	.6 - .7	.65
Molasses	78	7.2	—	63.6	—	.6	6.2	—	57.9	—	1.1 -1.5	1.3
Wet Grains	23.7	5.1	1.7	10.6	5.1	3.5	.2	1.5	6.6	2	4 -6	5
Dried Grains	91	21.2	7.5	41.7	16.	14.1	1	6.6	25.	7.7	1.2 -1.4	1.3

	Dry Matter	TOTAL				DIGESTIBLE					POUNDS TO A FOOD UNIT	
		Albuminoids	Fats	Carbo-hydrates	Fibre	Albuminoids	Amides	Fat	Carbo-Hydrates	Fibre	Variation	Average
	%	%	%	%	%	%	%	%	%	%		
Mangels	11	1.1	.1	7.8	1.	.4	.6	.1	7.4	.7	8 −12	10
Swedes	12	1.1	.2	8.5	1.3	.5	.5	.1	8.1	.8	8 −10	9
Turnips	8.8	1.	.2	5.7	1.1	.4	.5	.1	5.4	.7	10 −15	12.5
Carrots	13	1.2	.2	9.3	1.3	.5	.4	.1	8.9	.7	7 −10	8
Sugar Beet	25	1.3	.1	21.4	1.5	.5	.7	.1	20.3	.5	4 −5	4
Potatoes	25	2.1	.1	21	.7	.4	.7	—	18.9	—	4 −5	4
Pure Clover Hay	83.5	13.5	2.	37.1	24.1	5.5	3	1.7	26	11.3	2 −2.8	2.2
Grass and Clover Hay	83	9.5	2	39.5	26.3	4.2	1.5	1.1	25.3	12.4	2 −3	2.5
Timothy Hay	85	6.5	2	42.2	29.5	3.	1.	1.2	27.	14.2	2 −3	2.5
Lucerne Hay (Cut before flowering)	84	16.2	2.4	31.1	27	8.1	4.1	1.1	21.1	13	2 −2.5	2.2
Lucerne Hay (Cut in flwr.)	83.5	14.2	2.6	29.2	29.5	6.2	3.5	1.2	18.1	13	2.3 −2.7	2.5
Meadow Hay	82	9.7	2.	38.	26.3	4.2	1.3	1.	24.3	15.5	2 −3	2.5
Winter Wheat Straw	85	4.3	1.5	36	37.6	.5	.2	.5	13.3	18.8	4.5 −6	5
Barley Straw (Stiff)	85.7	3.5	1.4	35.9	39.5	.7	.2	.5	19.0	21.3	3.5 −4.5	4
Do. (mdm.)	85.	4.3	1.6	36.8	37.2	.9	.2	.6	19.5	20.1	3.5 −4	3.7
Do (good)	85	5.2	1.8	38.1	34.9	1.1	.3	.7	20.2	18.8	3 −4	3.5
Oat Straw (Stiff)	85	3.6	1.6	35.6	38.5	.9	.2	.6	16.4	20.8	4 −5	4.3
Do. (Mdm.)	85	3.9	1.9	38.	35.4	1	.3	.7	17.5	19.1	3.5 −4.5	4
Do (good)	85	4.	1.8	40.1	34.1	1.1	.3	.7	18.5	18.4	3.5 −4	3.8
Pea Straw	86.4	9.	1.6	33.7	38.5	3.5	.9	.7	19.9	17.3	3 −4	3.5
Bean Straw	81.6	8.1	1.1	31.	36	13.2	.8	.6	21.1	15.5	3 −4	3.5
Wheat Chaff	84.	4.7	1.7	37.1	30.4	.9	.5	.5	16.7	14.6	2.5 −3.5	3.
Barley Chaff	85.5	2.9	1.5	38.4	29.9	.5	.3	.5	17.3	14.4	2.5 −3.5	3.
Oat Chaff	86.2	5.	2.5	41.5	26.7	1.4	.5	.8	20.	13.6	2.5 −3.5	2.6
Green Clover (young)	17	4.3	.6	7.2	3.1	2.1	1.3	.4	6	2.1	6 −9	7
Do. (begin'g. of flwrg.)	19	3.4	.7	8.	5.2	1.7	.8	.5	6.3	3.1	6 −9	7
Do. in full flower)	22	3.2	.7	10.	6.5	1.5	.7	.4	7.2	3.3	6 −9	6.8
Green Grass and Clover	23	3.2	.8	10.7	6.	1.5	.5	.5	7.2	3.1	6 −8	6.5
Perennial Rye Grass	24.8	2.9	.7	11.5	7.1	1.3	.5	.3	7.4	4	5 −7	6.5
Italian Rye Grass	25	3.4	1.	11.6	6.2	1.3	.8	.5	7.7	3.6	5 −7	6
Timothy Grass	33.1	3.1	1.	17.6	9.2	1	.6	.5	11.1	4.8	5 −7	5.3
Pasture	20	3.5	.8	9.7	4.	1.7	.8	.4	7.3	2.6	5.5 −7.5	6.3
Meadowgrass (before flwrg.	25	3	.8	13.1	6.	1.5	.5	.4	9.1	3.9	5 −7	5.4
Do(in flower)	30	3.1	.8	14.8	9.2	1.3	.7	.4	10.1	5.4	5 −7	5.3
Do (bleached)	19.2	3.5	.5	12.8	6.6	1.3	1.1	.4	6.3	3.2	6 −8	7
Green Oats	23.2	1.9	.6	10.4	8.5	1.2	.2	.4	6.5	4.9	7 −9	7
Do. Vetches	16.5	3.5	.5	6.2	4.6	1.7	.9	.3	4.2	2.1	8 −12	10
Do Vetches & Oats	17.5	3.2	.5	7.2	5.1	1.4	.8	.3	4.9	2.3	8 −12	10
Do. Peas	16.5	3.8	.5	6	5.	1.8	1	.3	3.8	2.6	8 −12	10
Do. Beans	15.0	3.2	.8	5.7	3.3	1.5	.8	.5	4.1	1.6	8 −12	10
Do. Maize	17.2	1.4	.4	8.9	5.	.4	.4	.2	5.7	2.8	8 −12	10

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